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THE COUNTRY AROUND

INGLEBOROUGH,

WITH PARTS OF

WENSLEYDALE AND WHARFEDALE.

(EXPLANATION OF QUARTER-SHEET 97 S.W.
NEW SERIES, SHEET 50.)

BY

J. R. DAKYNS, M.A., R. H. TIDDEMAN, M.A., F.G.S.,
W. GUNN, F.G.S., and A. STRAHAN, M.A., F.G.S.

(WITH NOTES BY C. FOX-STRANGWAYS, F.G.S., AND J. G. GOODCHILD, F.G.S.)

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P R E F A C E.

THE geological mapping of the Quarter-Sheet described in the following chapters was begun in the western part by Mr. (now Professor) Hughes, and on his retirement from the staff was carried on, first by Mr. Goodchild, and then by Messrs. Dakyns, Tiddeman, Gunn, and Strahan, a small portion of the northern margin having been done by Mr. Fox-Strangways. The field-work was prosecuted under the supervision of Messrs. Aveline and Howell.

The present Memoir has been written by the officers chiefly concerned in the mapping, Messrs. Dakyns, Tiddeman, Gunn, and Strahan, notes having been supplied by Messrs. Fox-Strangways and Goodchild, and the whole has been arranged and edited by Messrs. Dakyns and Strahan.

Among the features of special geological interest in the map, and in the present description of it, reference may be made here to the exposures of the Silurian platform, which in some of the dales has been revealed under the base of the Carboniferous Limestone; to the outliers of Millstone Grit on Ingleborough, Whernside, and some other of the higher fells, and the enormous denudation which they demonstrate; and to the great double Craven Fault as well as a second large dislocation which in the present Memoir is distinguished as the Dent Fault. There are many topographical features of interest in the district, such for instance as the caves in the platform of limestone on which Ingleborough stands. A bibliography of the more important geological books and papers relating to the district is appended.

ARCH. GEIKIE,
Director General.

Geological Survey Office,
28, Jermyn Street, London,
16th May 1890.

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THE GEOLOGY OF
THE COUNTRY AROUND
INGLEBOROUGH,
ETC. ETC.

7

THE GEOLOGY OF
THE COUNTRY AROUND
INGLEBOROUGH,
ETC. ETC.

CHAPTER I.—INTRODUCTION.

By J. R. DAKYNS.

PHYSICAL GEOLOGY AND TABLE OF STRATA.

THE country comprised in this map is situated between the towns or hamlets of Kettlewell, Arncliffe, Horton-in-Ribblesdale, Ingleton, Dent, Hawes, Bainbridge, and Aysgarth, which latter is just outside the limit of the map.

It embraces the following dales: Littondale, the part of Wharfedale above Kettlewell, the upper part of Bishopdale, Semmerdale, Duerley, Snaizholme, Widdale, the southern side of Wensleydale from Hawes nearly to Aysgarth, Ribblesdale above Horton, Chapel-le-Dale, Kingsdale, Dent, and a portion of Garsdale.

It thus comprises the very centre of the river-systems of South Yorkshire and Lancashire, as here are found the sources of the Wharfe, the Ribble, the Greet, the Dee an important tributary of the Lune, and several of the affluents of the Ure.

It contains the following points of maximum elevation above the sea: Addlebrough 1,564, Blea Moor 1,753, Rise Hill* 1,825, Wold Fell 1,829, Greenfield Knot 1,959, Wether Fell 2,015, Yockenthwaite Moor 2,109, Dodd Fell 2,189, Fountain Fell 2,191, Widdale Fell 2,203, Crag o' Dent 2,250, Pennegent† 2,273, Buckden Pike‡ 2,302, Ingleborough 2,373, and Whernside 2,414.

As may be supposed, this country, with the exception of some rich land in the valleys, particularly in Dent and Wensleydale, is composed entirely of fell and moorland. Geologically it consists of an elevated plateau of Carboniferous Limestone inclined eastwards, on which stand hills of Yoredale Rocks capped with Millstone Grit; while in the western dales, owing to the general easterly dip, the streams have cut down through the Carboniferous beds and exposed great thicknesses of Silurian Rocks.

The limestone, where not covered with clayey drift and peat, gives growth to a short sweet grass between the scars of rock, save on the bare plateaus known as *Helks*. The sandstones, shales,

* Sometimes spelt Risell or Rysell. Here and elsewhere through the Memoir the spelling given on the Ordnance Map has been adopted. In cases where there is reason to think this spelling may mislead, the version commonly in use is also given.

† Frequently spelt Penyghent.

‡ This hill seems to have been formerly called *Settingset*.

and Drift afford pasturage of a coarser kind. There is no arable land save in the low ground near Ingleton.

Physically the aspect of the country is that of a succession of terraces formed by the outcrops of various beds of limestone and grit; the top of each bed of limestone being generally marked by a row of pot-holes, while springs gush out along the base. The rocks contained in this map range from Lower Silurian up to Coal-Measures. Lower Silurian rocks are exposed in Chapel-le-Dale, north-east of Ingleton, and at Horton-in-Ribblesdale, Upper Silurian strata in Ribblesdale below Horton and in Crummack. The Coal-Measures occur, at a corner of the map, near Ingleton only, and being on the west side of the Craven Fault are more intimately connected with the country on the west.

The rest of the map, and by far the larger portion of it, consists of Carboniferous Rocks in an unbroken series from the Basement Conglomerate to the grit of Buckden Pike; this last, the highest bed occurring in this map, is one of the grits above the Kinderscout Grit, probably one of those of Follifoot Ridge.

The unconformity between the Carboniferous and Silurian groups, one of the most marked in the British Isles, can be studied in several places within this Quarter-Sheet.

Annexed is a table of the strata occurring in this map:—

RECENT AND POST-GLACIAL.	{ Alluvium. Peat. River Terraces.	
GLACIAL.	{ Boulder Clay Sand and Gravel }	Partly contemporaneous.

		FEET.	
COAL-MEASURES; faulted against the Lower Carboniferous Rocks.			
MILLSTONE GRIT; the whole thickness not seen	-	471	
CARBONIFEROUS LIMESTONE SERIES.	YOREDALE ROCKS.	Cherty beds, sandstone, and shale; variable	- 0 to 90
		Main Limestone	- 50 to 100
		Sandstone and shale	- 70 to 100
		Underset Limestone (thins away south)	- 0 to 80
		Sandstone and shale with two thin limestones	- 100 to 345
		Middle Limestone	- 15 to 110
		Sandstone and shale	- 30 to 150
		Simonstone Limestone	- 15 to 60
		Sandstone and shale	- 30 to 180
		Hardraw Scar Limestone (sometimes in two divisions)	25 to 80
		Sandstone and shale thinning out south-eastward	- 0 to 140
		Gayle Limestone.	
		Shale thinning to the south	- 0 to 9
		Hawes Limestone.	
		Sandstone and shale thinning southward	- 0 to 14
Limestone. Thick "scar" limestone.			
Basement Conglomerate.			

Unconformity.

UPPER SILURIAN.	} Coniston Flags.
LOWER SILURIAN.	
	} Coniston Limestone.
	} Greenish grits and slates, presumably on the horizon of the Volcanic Series of the Lake District.

CHAPTER II.—SILURIAN ROCKS.

By W. GUNN.

IN the southern part of this Quarter-Sheet there are four separate patches of Silurian Rocks. Two of these are near Ingleton and contain only Lower Silurian, while the two farther east, at Crummack and Horton-in-Ribblesdale respectively, comprise both Upper and Lower Silurian strata. But these last two patches are only separate as regards this map, being connected in the sheet to the south (Quarter-Sheet 92 N.W.). A fifth small area of Upper and Lower Silurian rocks lies in the north-western corner of the map, for the description of which the reader is referred to the Memoir on Quarter-Sheet 98 S.E., and to that on 97 N.W. (in preparation). The strata come into sight in a small gill near Underwood. In Helmside Gill five or more mica-trap dykes traverse the Coniston Limestone.

The following table gives the order of succession observed in the southern part of this Quarter-Sheet.

Upper Silurian.	{	Coniston Flags.	{	Tough grits and flags. Cleaved mudstone or slate. Conglomerate.
<i>Unconformity?</i>				
Lower Silurian.	{	Coniston Limestone Series. "Green Slates and Porphyries."	{	Mudstone or strongly cleaved slate. Limestone and shale. Greenish grits and slates.

In the following description use has been made of papers by Phillips,* Sedgwick,† and more especially of one by Prof. Hughes,‡ who surveyed much of the area. Mr. Goodchild also, who went over portions of the ground, furnishes M.S. notes, which have been drawn upon in several instances.

LOWER SILURIAN ROCKS.

Chapel-le-Dale Area.

The largest and most important area of Lower Silurian strata is that which occupies the lower part of Chapel-le-Dale§ and the adjacent valley of Thornton Beck. It stretches about 2½ miles

* *Trans. Geol. Soc.*, ser. 2, vol. iii. p. 1. 1829.

† *Quart. Journ. Geol. Soc.*, vol. viii. p. 35. 1852.

‡ *Geol. Mag.*, vol. iv. p. 346. 1867.

§ In the following description the stream which flows down Chapel-le-dale is called Ingleton Beck, and that which flows down Kingsdale Thornton Beck, the names they are generally known by. On the Ordnance Maps the former is named The Doe or The Dale Beck, the latter The Twis or The Greet. The name Doe, however, though sometimes applied to Thornton Beck, is never used for Ingleton Beck.

FIG. 1.

Section along Chapel-le-Dale from near Ingleton to God's Bridge.

By W. GUNN.

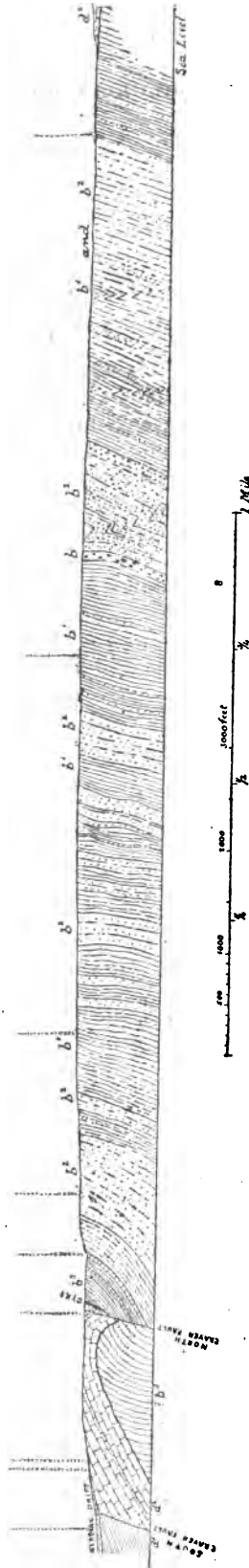
S. 39 W. Mt. Pleasant.
Richmond Road.

Richmond Road. Beck. with.

N. 39 E. S. 45 W.
Richmond Road.
Milestone Lan-
caster 19 miles.

Richmond Road.

N. 45 E.
Near God's
Bridge.
Dale Beck.



Scale 3 inches to a mile.

- d⁵. Coal-measures.
 - d⁴. Great Sear Limestone.
 - b³. Conistone Limestone Series.
 - b². Grits
 - b¹. Shales
 - b. Conglomerate
- "Green Slates and Porphyries"

in a north-easterly direction from the North Craven Fault near Ingleton, across the strike of the beds to a little below God's Bridge, where the Carboniferous Limestone crosses the stream—being bounded on all sides except the west by nearly level beds of this limestone.* The Silurian rocks here consist of a thick series of greenish grits and slates, surmounted by limestone and calcareous shales, which being close to the fault on the S.W. are the highest beds seen. The dip is everywhere high to the S.W., and there seems a continuous ascending section all down the valley from God's Bridge, so that there must be here exposed a thickness of about 10,000 feet of strata. The accompanying section differs slightly from that given by Prof. Hughes.†

Commencing with the lowest beds and starting from God's Bridge (where there is a natural bridge of Carboniferous Limestone for some 200 yards), the stream makes a sharp bend and a strong feeder of water comes out. Here we lose sight of the limestone, and here probably is its base, but we do not see anything of the Silurian rocks till we get 200 yards or so further down the stream, the banks being composed of Drift. Then we find greenish-grey slates with gritty beds above them in the bed of the stream, dipping S.W. at 75°–80°. Below this the river runs through spreads of alluvium till we get near Beezley's, but rock appears on both sides of the valley, though on the west side near the base of the Carboniferous Limestone, and on the east side near the main road, it is more obscured by Drift than in the part nearest to Ingleton. However there is enough to show that we pass through a great thickness of fine grey grits and slates, some greenish, till below Dale House we come upon a thick series of grits some of which are coarse. The dip is everywhere high, from 50° to 80°, and in one or two places seems reversed, but on the whole maintains pretty steadily the same south-westerly direction. It is even vertical in places and the reverse dips may be only apparent and due to inversions. The mass of grits with subordinate slaty bands below Dale House is probably 800 feet thick or more. It is well seen west of Twisleton Dale House, where the upper part is a conglomerate. On the east side of the valley this conglomerate consists mostly of white or grey quartz-fragments mingled with pieces of red felspar, and is hard and tough. Mr. Rutley, who has examined specimens, calls it *arkose*. There is no doubt about the detrital character of this rock, though it has been regarded by some as *porphyry*. Boulders of it have been carried down the valley during the Glacial Period to near the slate-quarries. These beds seem to be contorted in places east of the river, and the bedding is often obscure. The conglomerate is much veined with quartz.

* The presence of the older rocks here (called *schistus*), and the unconformity of the overlying limestone, were first described by Playfair: See his "Illustrations of the Huttonian Theory" (1802), pp. 217–219, where among other things he gives an account of the section at Thornton Force.

† *Geol. Mag.*, vol. iv. p. 346. 1867.

From here to beyond Dale Barn there is a good deal of Drift, but there seem to be alternations of grits and slates, the latter predominating at first, while afterwards to beyond Beezley's gritty beds abound. Only a few of the more marked gritty beds can be traced with certainty all across the valley, some being probably lenticular.* At Beezley's the river enters a charming ravine by a number of waterfalls, and runs for a long distance mainly through slaty beds with subordinate gritty bands, in the upper part of which series, on either side of and close to the river, are old slate-quarries. The slates are lead-coloured, with a slight greenish tint, which becomes more decided on weathered surfaces, and dip S.W. at 85° . These are the beds seen below the Carboniferous Limestone at Thornton Force in the next valley to the westward. Leaving these slates the river passes a well-marked gritty band by a series of waterfalls, and affords a fine section, though it is difficult to follow. This band of greenish-grey grit with only a few thin slates must be at least 600 or 700 feet thick, and can be traced continuously across the valley of Ingleton Beck from the S.E. to near Long Chimney, when it disappears under Drift. In Thornton Beck it again forms a picturesque series of waterfalls. Above this lies a well-marked slaty band which has been largely quarried in both valleys, but more especially on both sides of Ingleton Beck. It has been described both by Phillips and Sedgwick in the papers referred to above.

The slates of this band are greenish, but often weather to a purplish colour. Prof. Hughes describes them as light-green and olive. Prof. Sedgwick says: "The quarries on the Thornton Beck section are spoiled by joints and fractures, and are now deserted, but the quarries on both sides of the other rivulet (Ingleton Beck) are still worked extensively. The slates are coarser than the fine greenish-blue slates of the central group of Cumberland, but resemble them in colour. Some of them are marked with beautiful dendritic coverings of pyrites, and occasionally studded with large bright cubes of that mineral. Good sound roofing-slates are, however, obtained without any taint from pyrites. The slaty planes are vertical and exactly parallel to hard beds of *calliard* which rise at their side; and hence it follows that the planes of fission are parallel to the original laminæ of deposit."† The dip here ranges from 75° to 90° , and the slaty band must be from 300 to 500 feet thick, but below the slate-quarries Drift obscures the section. In one place some thin sandy beds occur. Lower down in the eastern bank of the stream we arrive at the highest beds of the section—blue limestone much cleaved in places, passing up into bluish cleaved calcareous slates or shales—the equivalents of the Coniston Limestone. The beds seem to be rolling and the dip is not so

* A few of the more marked beds of grit are distinguished on the map.

† *Quart. Journ. Geol. Soc.*, vol. viii. p. 45. 1852.

high as usual. Prof. Hughes says: "These green slates pass up into a thin bedded shivery slate, often breaking up when weathered into small wafer-like fragments. These in turn pass up into more sandy slate, with calcareous bands forming the base of the Coniston Limestone. The limestone has here yielded only some obscure traces of fossils, being considerably altered by proximity to one of the Great Craven faults. There would appear, therefore, to be a passage from the green slates to the overlying Coniston Limestone, as we find that not only does the dip of the two formations agree exactly, but that there are beds intermediate in lithological character between them."* Prof. Sedgwick obtained from these calcareous beds near the upper dyke (hereafter described) the following fossils:—

Monticulipora fibrosa, Goldf.

Halysites catenularia, Linn.

Orthis Actonia, Sow.

Of the corresponding limestone in Thornton Beck, he remarks: "It contains a few encrinite-stems, obscure corals, and shells of which the species could not be determined." The limestone is fairly well seen in a little stream S.W. of Skirwith, where it dips S.W. at about 30°, and is mostly bluish and slaty. In the road N.E. of Twisleton Manor House the limestone is brownish and dolomitic, with many strings and nests of calcareous spar. Mr. Goodchild supplies the following detailed description of the section seen in Thornton Beck †:—

"On the north-east side of the North Craven Fault, a good section of these rocks is exposed in the course of the Twis below Twisleton Hall. The rocks in this section, as they mainly do elsewhere throughout this area, dip, on the whole, southward at high angles. Successively lower beds, therefore, rise to the surface as the sections are followed towards the north, and the highest strata are they that lie nearest to the fault. These highest beds consist chiefly of dark blue-grey shales, more or less calcareous in character, and occasionally developing into impure argillaceous limestone along certain bands.

"As lower beds rise to the surface the rocks tend more and more to assume the character of limestone; and eventually, after a little over a hundred feet of shales have been passed through, consist mainly of well-bedded limestone, full of fossils of a Coniston facies. This limestone closely resembles that which is referred to a Coniston horizon elsewhere throughout this area. The thickness seen exceeds 100 feet. Below it the strata for a short distance are not clearly exposed, probably because they yield more rapidly under denudation than the harder rocks above, but partly because Glacial Drift, and fallen rocks from above, obscure this part of

* *Geol. Mag.*, vol. iv. p. 349. 1867.

† Called the Twis on the Ordnance Map, a name, however, which seems to be not generally known.

the section. About 50 yards to the north, dull, earthy limestone graduates downward into the older beds through close alternations of bands of impure limestone and calcareous sandstone. Strata of the same character occupy the west bank of the stream at a much higher level, close to the old cart-road leading up from this part of the beck to Thornton.

"Below the calcareous members of the series come thinly-laminated, smooth-textured, papery mudstones, with a prevailing tinge of pale greenish-grey, ranging thence to drab, and to dull lead-colour, the faces of the bedding-planes being often glossy, or almost silky in texture. Slates somewhat lower down in the series have been quarried in the west bank of the Twis, and may be well examined there. They form part of the original "Green Slates" of the older writers. The strata, from the base of the limestone down to the base of these green slates, dip with tolerable regularity at high angles towards the south; and can scarcely fall short of 250 to 300 feet in thickness.

"A considerable thickness of alternations of grauwacke and smooth-textured mudstones which succeeds, is characterised by a pale tea-green, or glaucous tint which ranges occasionally on the one hand to drab, and on the other to lead-colour. The finer textured beds are all more or less affected by cleavage, which cuts the rocks, in a general way, along the strike, and frequently coincides in hade with the inclination of the strata affected.

The unequal resistance to denudation offered by the alternately hard and soft beds just mentioned gives rise to a pleasing diversity of scenery in the course of the stream and its immediate neighbourhood; as the craggy, and occasionally well-wooded slopes on its banks accompany a succession of rocky waterfalls in the bed of the stream, while at a higher level some fine mural scars of grey Carboniferous Limestone, lying horizontally across the edges of the older beds, present a striking contrast to the nature of the scenery below.

"Higher up the Twis this grauwacke series gives place to a lower group of glaucous mudstones, similar in general character to the beds above mentioned as being quarried for "Green Slates" on the west bank of the stream. These lower mudstones are remarkably smooth-textured, and locally exhibit a lustre like that of silk, on many of the divisional planes. They readily split into slabs along the bedding-planes, as the planes of cleavage are not generally sufficiently well developed to cause the beds to part with greater facility in other directions. Though not quarried at this particular locality, their presumed equivalents are largely worked in the next valley to the east. The base of this lower mudstone group is not seen in the Twis, as the horizontal sheets of Carboniferous Limestone begin to extend continuously across the edges of the older rocks in the bed of the stream at Thornton Force. The downward sequence of these strata has therefore to be traced along the line of section in the Ingleton Beck area.

"In Ingleton Beck and the banks adjoining, the downward sequence described as occurring in the Twis can be easily traced to the

same horizon. Below the second bed of mudstone here, however, there is abundant evidence of the existence of between nine and ten thousand feet of alternations of beds of tough grauwacke and slabby mudstone, with here and there a band of fine conglomerate, sufficiently granitoid in regard to its constituents to merit the term Arkose. All these beds have more or less of a dull-greenish tint, ranging locally to pale tea-green, and elsewhere to dark lead-colour, mica and quartz, always water-worn, forming, along with detrital felspar, the bulk of their constituents. They therefore offer a marked contrast in this respect to those which occupy the same relative position to the Coniston Limestone in the Lake District, only a few miles to the north-west. In the Craven area they nowhere exhibit the slightest approach to a volcanic character, but, on the contrary, consist of distinctly detrital materials, their main constituents, moreover, the quartz and mica, being conspicuous by their absence from all, or nearly all, their assumed equivalents in the Lake District. Nor on the other hand do they ever approach the character of the slates of the Skiddaw Series."

Besides the sections, seen in the streams, the grits and slates crop out in Chapel-le-Dale, in the many rounded bosses of rock which stick up through the Drift, and particularly in many sections in and near the main road which traverses the valley on its eastern side.

Jenkin Beck Area.

About three-quarters of a mile south-east of Skirwith, in Jenkin Beck, a detached exposure of the Coniston Limestone consists of calcareous shale or slate with thin blue limestone-bands, while a little to the north-west another outcrop away from the stream shows calcareous shale with concretionary blue limestone-bands which turn to rotten-stone on weathering. The beds dip S.S.E. nearly, at angles of from 50° to 80° . A short distance to the eastward they pass under the Carboniferous Limestone, and on the west are bounded by the same fault which cuts off the Coniston Limestone in Ingleton and Thornton Becks.

Crummack Area.

Professor Hughes first drew attention to the presence of Lower Silurian Rocks in this area.* The highest member only of the group, namely, a part of the Coniston Limestone and its associated beds, is brought up by an anticline, probably the same as that which ranges to Crag Hill in Ribblesdale in an E.S.E. direction. The sections are poor and the lines of boundary uncertain owing to Drift. At Austwick Beck Head an interesting section shows the conglomerate, which Prof. Hughes took for the base of the Upper Silurian group, resting on an irregular cleaved

* *Geol. Mag.*, vol. iv. p. 346. 1867.

mudstone of which there is little seen and that much weathered. This is the northern limb of the anticline, the southern not being shown on this side of the valley. To the southward some dark shales with calcareous nodules presumably form part of the Coniston Limestone shales. On the other side of the valley the Coniston Limestone dips S.S.W. at 50° , close under the scar of Carboniferous Limestone, and again in the field west of Moughton Lane there is a little boss of cherty limestone. Further west still in Moughton Sike, 100 yards above its junction with the stream coming from Austwick Beck Head, the limestone dips S.S.W. at 25° . It will be noticed that we include in the Lower Silurian group some mudstones and slaty bands overlying the limestone, and some shales which are probably calcareous. In Moughton Sike, near the point where it crosses Moughton Lane, some greenish beds perhaps underlie the limestone and form part of the Chapel-le-Dale Series. The boundary of the Lower Silurian rocks here may be a fault or the anticline may be inverted and the greenish beds lie over the limestone. The only fossil reported from the Coniston Limestone of this area is a doubtful *Glyptocrinus* marked as from Hunterstye.

Horton Area (Fig. 2, p. 15).

The upper part of the Chapel-le-Dale series of greenish grits and slates appears in several places in the Ribble near Horton, from opposite the church northwards about a quarter of a mile, to the sharp bend in the stream at Row End. The lowest bed seen is a conglomerate. The dip is everywhere high, from 55° to 75° , and the direction about S.S.W. Some of the same beds are exposed also in the railway-cutting at Pettythorn Barn and in the fields to the westward, as also in the streams coming from Bee Croft Hall and Bee Croft Hall Plantation. The dip ranges from 25° to 35° west of south and varies in amount from 40° to 70° . There is much Drift and no attempt has been made as in Chapel-le-Dale to separate the grits from the slates, nor can any correlation be made between any of the beds in the two areas. There is a good section in the railway-cutting about a quarter of a mile south of Horton Station, where a long and deep cutting for the most part in Boulder Clay has gone through rock for about 150 yards. The beds dip to the west of south at high angles, averaging probably as much as 50° , so that about 300 feet of rock must be here exposed. In approaching the section from the north we pass grits in the lower part for 65 yards, then a gap of 36 yards where nothing is visible, and then again rock for 55 yards. In the lower part of this are many alternations and the rock seems much crushed, with three veins running W.N.W., and in one place we see a calcareous breccia 3 to 4 feet thick. Higher up occurs a band, 3 to 4 feet thick, of compact whitish limestone, which is capped by grits. These rock-bosses are finely rounded and show numerous glacial striæ ranging nearly north and south. The

following account of this section is taken from Mr. Goodchild's notes:—

“The strata consist of close alternations of glaucous, or pale-greenish lead-coloured grits and sandstones, very much like the beds belonging to the Coniston Grit Series, courses of greenish-grey and olive mudstones, more or less porcellanous in texture, and more thinly bedded argillaceous partings, generally affected by cleavage. Irregular bands of calcareous matter, occasionally assuming the character of lenticular bands of limestone, occur in the higher part of the section; but clearly are not such as could be traced any distance at the surface. Traces of carbonised matter, apparently of vegetable origin, may be observed on some of the planes of deposition; but no definite organic structure can be clearly made out. Otherwise the rock seems quite devoid of fossils in any form. Here and there some of the beds include galls or lenticular flakes of some shaly rock, not altogether unlike the Skiddaw Slates; but no true conglomerates occur in this part of the section. Contorted and uneven lamination, contemporaneous with the rock, occurs on a small scale; otherwise the bedding is remarkably even and regular.”

The prevalence of Drift makes uncertain the position of the boundary between the Upper and Lower Silurian groups, and the thin band of Coniston Limestone shown on the map appears only in the stream called Dow Gill to the east of Horton at Town Head. Here just at the foot of Dow Gill Plantation the green slates and grits crop out in the bed of the stream close up to the base of the Scar Limestone. They dip S.S.W. at about 60°, but are much crushed, there being several faults or veins running N. 30° E. Mr. Goodchild noticed galena and barytes in the rock here. The greenish-grey grits and mudstones pass up into slates with calcareous concretions full of Lower Silurian fossils, and forming the lower part of the Coniston Limestone. The dip flattens at about 150 yards down the stream, and then turns to the N.E., so that the Coniston Limestone lies in a syncline, which is cut off on the west side by a fault which ranges about north-west and brings up again the green slates. Traces of galena and pyrites occur in the rock adjacent. The green slates and grits west of the fault for about 70 yards dip steeply, from 55° to 65°, about S.S.W., but opposite Town Head we lose the section, nor do we get a view of Lower Silurian rocks again on this side of the valley owing to the thick coating of Drift. Prof. Sedgwick first pointed out the resemblance between these strata and those near Ingleton below the slate-quarries,* and obtained from the calcareous beds numerous fossils. The lists, however, which he gives, as well as those quoted in Sedgwick and McCoy's *Palæozoic Fossils*, include specimens from more than one horizon, some being undoubted Upper Silurian forms. During the progress of the Survey specimens of the following have been obtained.

* *Quart. Journ. Geol. Soc.*, vol. viii. p. 48. 1852.

Fossils from the Lower Silurian Rocks of Horton in Ribblesdale.

Heliolites interstinctus, *Wahl.*
Monticulipora (Favosites) fibrosa, *Goldf.*
Streptelasma aequisulcata, *McCoy.*
Cheirurus.
Cybele verrucosa, *Dalm.*
Illænus.
Phacops.
Discina.
Leptaena sericea, *Sow.*
 " *transversalis*, *Wahl.*
Lingula ovata, *McCoy.*
Orthis Actoniæ, *Sow.*
 " *biforata*, *Schloth.*
 " *calligramma*, *Dalm.*
 " *elegantula*, *Dalm.*
 " *flabellulum*, *Sow.*
 " *vespertilio*, *Sow.*
Rhynchonella.
Strophomena grandis, *Sow.*
Modiolopsis, *sp.*
Murchisonia.

UPPER SILURIAN ROCKS.

Crummack Area.

The thin conglomerate mentioned before as seen at Austwick Beck Head forms the base of the Upper Silurian group. It dips N.N.E. under some slates which in turn must go under the flags and slates of Capple Bank. The Stockdale Shales of the Lake District do not appear to be present either in this area or in Ribblesdale to the east, and there is no doubt that the alternations of shivery slate with variable and thin grits which overlies the Coniston Limestone here both to the north and south, belong to the lower section of the Coniston Flags, the division marked A. C. 3 in Prof. Hughes's paper, and called Lower Coniston Flags by Mr. Marr. The Middle Grits which overlies them—called by Mr. Goodchild "Wharfe Grits"—only just come into this map, if at all, to the S.W. of Crummack, the boundary between the two running across the valley inside the sheet to the south. There is much Drift between Crummack and the beck, but south of Crummack the flags or slates in several places dip nearly south at angles of 25° to 30°. East of the beck more rock is seen about Hunterstye. The dip is lowest near the limestone, being 15° to 20° and varying in direction between S.S.W. and S.S.E. It increases southward to 40° or so near the edge of the map and the direction is due south. The thickness of these beds probably amounts to 800 or 900 feet. The sections are not numerous enough for any gritty bands to be traced here, though one or two marked gritty bands occur in the same series in Capple Bank on

the north side of the anticline of Coniston Limestone, where the dip reaches 50° to 80° , the direction being N.N.E. A thickness of from 500 to 600 feet of these Lower Flags, which we pass without coming to the "Middle" or "Wharfe Grits," consists mostly of cleaved mudstones or slates, sandy and micaceous in places, with two gritty bands subordinate to the flags and slates. The larger of these, which is 50–60 feet thick, has been traced right across the valley under Capple Bank. About 100 feet higher in the series a thinner bed of grit, 20 feet thick or so, can be traced for a short distance, crossing Moughton Lane just at its head, and dipping N.N.E. at 60° to 65° . Just above this comes a peculiar banded slate which has been quarried at the Moughton Whetstone Hole, and is described by Prof. Sedgwick as follows:—"We there find (alternating with the harder grits) a kind of whet-slate or flagstone which is divided into rhombohedral solids by two sets of cross-joints. Many of these regular solids have undergone a partial decomposition shown on the planes of fracture by beautiful coloured rings (exactly like those occasionally seen in flint-pebbles); which, commencing irregularly at the outer surfaces, gradually become more symmetrical as they diminish in size and approach the centres of the several solids."*

This banded slate can be traced above the grit-bed last mentioned; it crosses the end of the lane where the gate opens on to the moor, but does not seem to have been noticed in any other section. There is no doubt that this Whetstone-bed belongs to the upper part of the Lower Coniston Flags. *Monograptus dubius*, Suess., *M. Nilsoni*, Barr., *M. uncinatus*, Tullb, and *Orthoceras primævum*, Forbes, have been collected by Mr. Marr† from the Moughton Whetstone Hole.

Cleavage is generally noticeable in these flags. Several places may be mentioned, e.g., the east side of Crummack Beck about 150 yards from the edge of the map, and east of the lane just at the edge, where the cleavage strikes about E.S.E., while the bedding strikes E. On the north side of the anticline, in Moughton Lane and at the west end of Capple Bank, the cleavage coincides with the strike of the beds, which is here E.S.E. and W.N.W.; but the dip of the cleavage-planes differs from that of the beds, for while the latter dip N.N.E. at 70° , the cleavage-planes dip S.S.W. at 35° to 40° .

Ribblesdale Area.

The Upper Silurian strata in this valley occupy all the area south of the Lower Silurian group already described about Horton. The beds resemble those of the Crummack Valley, but, in addition to the Lower Coniston Flags, include the lower part of

* *Quart. Journ. Geol. Soc.*, vol. viii. p. 52. 1852.

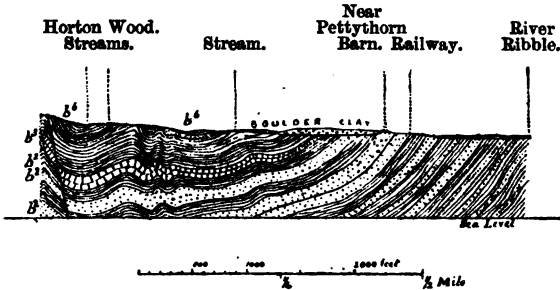
† *Geol. Mag.* for 1887, p. 37. I am informed by Mr. Marr that he is now inclined to refer *Monograptus uncinatus* to *M. Flemingii*.

the Middle Series of grits, which latter occupies the south-east part of the area, west of Dove Cote and Newland House. The central part of the valley being obscured by Alluvium and Drift, it will be convenient to take each side separately. On the east side the flags and sandy striped slates with some subordinate gritty bands may be seen in numerous places from Hardlands Barn southwards by Beckdale Barn to Redding Barn. They are thrown into many undulations, ranging nearly E.S.E., or between that and E., and one of the flag-bands has been quarried at Hardlands Plantation. This is one of the lowest beds seen, as Drift obscures the ground to the northward and covers up the junction with the Lower Silurian strata. There is a subordinate tough grit-band seen N.E. of Hardlands Plantation and a more marked band, probably the same, N. of Redding Barn. Cleavage prevails extensively in all the beds more or less, its general strike being nearly E. and W. or W. 15° N. The undulations cause the boundary between the flags and the overlying grits to be tortuous, as will be seen on the map. It seems to be broken by a fault west of Dove Cote. The higher part of the grits is obscured by Drift. The dip is nowhere very high on this side, but ranges from as low as 4° up to about 30° .

On the west side of the valley the section is somewhat similar. The base is just as obscure. The flags, slates, and subordinate grits are thrown into numerous undulations, which for the most part seem short and do not extend to those on the opposite side of the valley. The undulations are gentle at first, but as we go southwards the angles of dip increase so as to be in some places nearly vertical. One of the subordinate grit-beds in the Lower Flags occurs several times over. It seems to come up at Garth House on either side of a syncline, the north side of which is gentle and the south side so steep as to be vertical in places. South of this the same grit forms the boundary of the beautiful syncline of Horton Wood, the bedding of which is so clearly seen from the railway north of Crag Hill. On the north side the top of the grit coincides with the most northerly branch of the stream, and the dip is S. at about 30° , while when the grit turns up again south of the syncline it dips N.N.E. at 70° or more. Above it lie sandy flags and slates, while in the very centre of the syncline, close up under the Scar Limestone, comes the lower part of the Middle Grit, corresponding to that seen on the other side of the valley west of Dove Cote. Cleavage passes through grits, flags, and mudstones, and is specially noticeable in the centre of this syncline, where the beds are horizontal or nearly so. The section is an admirable one. At the south end of the map we are not far above the Coniston Limestone of Crag Hill, but a fault probably intervenes, the evidence for which will be given in the explanation of the sheet adjoining. *Monticulipora (Favosites) fibrosa*, Goldf., and *Pterinea*? were collected from the Coniston Flags of the ridge north of Crag Hill. The accompanying section illustrates the Silurian rocks of this western side of the valley.

FIG. 2.

Section from Horton Wood to the River Ribble near Row End,
by W. Gunn.



- b⁴. Coniston Flags and Grita.
 b³. Coniston Limestone.
 b². Grits } "Green Slates and Porphyries."
 b¹. Slates }

INTRUSIVE ROCKS.

Dykes of Mica-trap.

The only igneous rock seen in the Quarter-Sheet occurs in the Lower Silurian strata near Ingleton. Portions of a dyke or dykes appear in three or four places. The most westerly of these lies in Thornton Beck near the large fault which brings the Scar Limestone against the Silurian beds. The dyke is visible for 10 or 12 feet about the middle of the bend of the stream, which here runs S.E. It seems to be about 4 feet wide but may be more, and is only found in the bed of the stream. A description of a specimen by Mr. Rutley is appended (see description of No. 1 specimen).

Again in the road south of Skirwith a dyke of mica-trap appears for a short distance, and is also noticeable just over the wall on the south side of the road. It is only a few feet wide, and like the preceding is much weathered at the surface, so that it is difficult to get a good specimen for microscopic examination. Here again the dyke lies very near the fault mentioned before, as is shown in the section forming Fig. 1, p. 4 (see No. 2 specimen). Between these two places a dyke of somewhat similar character projects from the south bank of Ingleton Beck into the stream. More of it is exposed than in the other two cases, so that one can clearly detect its bearing, viz., E. 40° S., and determine its width to be 8 to 9 feet (see description of No. 3 specimen). This dyke lies a good way from the fault, but it is possible that all three are parts of one kersantite dyke, much decomposed at the surface. Professor Hughes has noticed another dyke of a similar character and 9 feet broad, further down the stream, near a sharp bend, and Sedgwick mentions two dykes in Ingleton

Beck,* but only the upper one was visible in 1883. Phillips also mentions two dykes as seen in Ingleton Beck.

The following petrological notes on specimens of the dykes described above are furnished by Mr. F. Rutley:—

No. 1. *Mica-trap. Dyke in Thornton Beck, near the North Craven Fault.*

Pale, greenish-grey crystalline rock containing small darker green crystals with a rather silky lustre. Fracture uneven; weathers to a greenish-brown crust in which the darker crystals are still discernible.

Microscope.—The rock appears to be much decomposed. It consists of magnesian mica, kaolinised felspar, and pseudomorphs of calcite or dolomite. The forms of these pseudomorphs are, however, too irregular to admit of any positive conclusion concerning the nature of the original mineral. These crystals and pseudomorphs lie in a somewhat decomposed microcrystalline groundmass. Crystals of apatite and small grains of pyrites are present. Since the felspars are too much altered to permit their specific recognition it is impossible to say whether the rock is a kersantite or minette. The term *mica-trap* covers the doubt.

No. 2. *Kersantite. Dyke in Road S.E. of Skirwith.*

Brownish-grey crystalline rock with small feebly-glistening greyish scales which on a smoothly-ground surface appear greenish-black. The specimen is decomposed, being a surface-chip.

Microscope.—A crystalline aggregate of felspar and magnesian-mica crystals, some of the former showing indications of the repeated twinning of the triclinic felspars. Yellowish, opaque grains are plentiful and may partly represent kaolin with a rusty stain, or leucoxene. Small crystals of apatite are visible. The rock also contains a little calcspar. It is essentially a decomposing mica-trap, or kersantite.

No. 3. *Kersantite. Dyke in Ingleton Beck.*

Reddish-brown to grey rock, which, under a pocket-lens is seen to consist of flesh-red felspar and dark scales of mica. Although a surface-specimen it is much fresher than the preceding.

Microscope.—By reflected light the section appears as a crystalline aggregate of flesh-red and white felspar (the latter has undergone partial alteration), dark crystals of magnesian mica, and black crystals and grains of magnetite. By transmitted light the presence of these minerals is also confirmed, while in addition small and sharply defined crystals of apatite are visible, and also a little calcspar. The felspar seems partly to owe its redness to rusty stains which probably result from peroxidation of the iron

* *Quart. Journ. Geol. Soc.*, vol. viii. p. 46. 1852.

in ferruginous minerals. The red-stained felspar is considerably altered, but it does not appear to be orthoclase. Some of the less decomposed felspars are triclinic.

An interesting feature in this section is the occurrence of a granule of magnetite in the middle of a patch of calcspar. It should however be mentioned that the magnetite although surrounded by calcite *in this section* may, at a point outside the plane of section, have been attached to the normal constituents of the rock, and its isolated appearance in the calcspar may be merely due to its having projected into a cavity subsequently filled up with calcite.

About 40 yards further up Thornton Beck than the dyke first-mentioned (No. 1), we see in the bed of the stream, on the south side, a dyke-like mass some 5 yards by 3 yards, looking much like a whitish fine-grained felstone, and for which it seems to have been mistaken by some. Mr. Rutley describes it as "very compact pale bluish-grey rock, traversed by delicate veins of calcite. Fracture uneven. Can be scratched with a knife-blade, but less easily than an ordinary limestone. A scraped surface when touched with acid effervesces.

"*Microscope*.—Feebly translucent except along the calcite veins and on irregularly shaped spots, while there are also a few translucent and imperfectly annular markings suggestive of partially obliterated organic structures, such as the ossicles of crinoid stems. There are also numerous little irregular opaque specks, which, when examined by reflected light, are seen to be pyrites, and under similar illumination the rock-section itself appears white.

"By transmitted light the general structure of the rock, so far as its feeble translucence admits it to be seen, is finely granular. A greenish tint pervades the section and is most strongly marked along the calcite veins. It is apparently due to the presence of exceedingly thin scales of chlorite.

"There seems little doubt that this is a considerably altered sedimentary rock and that, apart from its calcite veins, it is also calcareous. A limestone or other calcareous rock in the proximity of an eruptive mass might readily become altered in a similar manner."

We are inclined, however, to regard it probably as a piece of fault-rock or fine fault-breccia made up mainly of comminuted limestone, which here forms the bulk of the walls of the fault.

CHAPTER III.—CARBONIFEROUS ROCKS.

INTRODUCTION.

By J. R. DAKYNS.

FOR convenience of description we will divide the country into the following districts:—

1. Ingleborough and neighbourhood, Ribbleshead, and Kingsdale with Leck Fell.
2. Dent and Garsdale.
3. Littondale.
4. Wharfedale with parts of Walden, Bishopdale, Semmerdale, Sleddale, Snaizholme, Widdale, and Wensleydale.

Ingleborough and its immediate neighbourhood was surveyed by Messrs. Tiddeman, Gunn, and Strangways; Ribbleshead and Kingsdale by Messrs. Dakyns and Strahan; and Leck Fell by Mr. Barrow.

District 2 was surveyed by Mr. Strahan; district 3 by Mr. Dalton; district 4 by Messrs. Dakyns and Strangways.

Before entering upon the detailed description of these districts, we will say a few words on the geology of the country as a whole.

The series of beds in Wensleydale is well known from the writings of Prof. Phillips, and his classification has been generally adopted by geologists. It is with some amplification substantially as follows, for the beds below the Millstone grit.

A. MAIN (or TWELVE-FATHOM) LIMESTONE.

Measures.

B. UNDERSSET LIMESTONE.

Measures, with two thin beds of limestone.

C. MIDDLE LIMESTONE (Sedgwick's Mosdale Moor or Wold Limestone).

Measures.

D. SIMONSTONE LIMESTONE (Sedgwick's Strong Post Limestone).

Measures.

E. HARDRAW SCAR LIMESTONE (Sedgwick's Black Marble).

Measures.

F. GAYLE LIMESTONE.

Measures, thin.

G. LIMESTONE.

} Sedgwick's Great Scar Limestone.

The measures between F and G are very thin. Phillips therefore took F as the top of his Carboniferous Limestone, and included the beds from A to F in his Yoredale Series. As we go south however from Wensleydale, we find the measures between E and F to become very thin, and at last to die away altogether.

The measures above the Middle Limestone contain one and sometimes two thin limestones. The lowest of these is full of *Producti* and was called by Phillips the Impure Productal Limestone. In some districts it is locally known as the Horseshoe from the appearance of the large *Producti*. It is nearly, if not quite, always present, and probably represents the limestone known further north as the Five-Yards Limestone of Alston Moor. The upper one is probably the equivalent of the Three-Yards Limestone of Alston Moor. The Underset is found as a very thin bed on the flanks of Whernside, but does not appear either on Ingleborough or Pennegent. The Main Limestone thins away near Kettlewell, though it may reappear above Grassington. The first important bed above the Main Limestone is the grit which forms the top of Ingleborough. Between this grit and the limestone there comes generally a mass of sandstone and shale of variable thickness. Phillips took the Main Limestone as the topmost bed of the Yoredale Series, including the measures above it in the Millstone Grit. In Wharfedale and in Coverdale a coarse grit lies immediately upon the limestone; this grit we believed to be a part of the Kinderscout Grit; and consequently we here took the Main Limestone as the top of the Yoredale Series. As the limestone is very persistent and its top generally well-marked by lines of swallow-holes, while the overlying beds are changeable, it is undoubtedly most convenient to take the top of the limestone as the division between the Yoredale and Millstone Grit Series.

As we go north we find that the beds associated with the limestone undergo considerable changes. At Coverhead, between Coverdale and Wharfedale, the top of the limestone consists of a thin bed of chert. Northwards this bed of chert swells out into a great thickness of cherty beds known as the Main Chert and the Black and Red Beds of Swaledale. These cherty beds contain in some places thin gritty partings. Still further north the Black and Red Beds lose their cherty character, and are replaced by a set of shales and grits, known as the "coal-sills," capped by a thin but very constant bed of limestone, known as the "little lime." Thus this little limestone corresponds to what has been taken by Phillips as the top of the Yoredale Series.

Over both the "little lime" and the Black and Red Beds we have a bed of shale succeeded by a set of flaggy sandstones known as the "Ten-Fathom Grit." The grit is succeeded by a thin calcareous bed and that by shale; and the shale is succeeded by a well-marked gannister-like sandstone. This sandstone passes southward into, or is replaced by the coarse conglomeratic grit of Ingleborough. This grit is by all geologists classed with the Millstone Grit, and it is undoubtedly one of the beds which in Wharfedale have been coloured as Millstone Grit on our published maps. It usually forms a conspicuous feature on the fells, and is easily identified from point to point. The distance between it and the Main Limestone is however very variable; in fact the grit seems to have been deposited in hollows eroded out of the lower

beds and thus lies on an uneven surface. It is succeeded upwards by a variable series of sandstones and shales, the several members of which have not been everywhere correlated from one hill-top to another. But from a comparison of the various sections which we have got, we offer, as probably safe on the whole, the following classification of the beds above the Main Limestone :—

MILLSTONE GRIT :—

Sandstone of Buckden Pike, not less than	-	70 feet.
Shale	-	50 „
Sandstone of Whernside Top	-	50 „
Shale	-	50 „
Sandstone of Widdale Fell (varying from 60 to 90 feet)	-	75 „
Variable series of sandstone and shale (from 100 to 184)	-	142 „
Pebbly grit, of Ingleborough, from 50 to 140	95 „	

YORED ALE BEDS :—

Shale and sandstone, from 0 to 120
Cherty beds from 0 to over 50 feet.

Nearly the whole of the country embraced by this map is remarkably free from faults ; but at Ingleton in the extreme south-western corner two large faults known as the Craven faults throw down the beds to the south-west, so that the Coal-Measures form the low ground about that town (Fig. 3, p. 27).

A small portion of the great fault which runs from near Kirkby Stephen by Cautley, Garsdale Foot, and Dent, to near Barbon, bringing up the Silurian Rocks on its western side, is included in the north-western corner of this map.

DISTRICT 1. INGLEBOROUGH AND NEIGHBOURHOOD, RIBBLE-HEAD, AND KINGSDALE WITH LECK FELL.

By J. R. DAKYNS, R. H. TIDDEMAN, and W. GUNN.

This district includes the upper part of Ribblesdale, the head of Crummack Dale, the whole length of the valley of the Dale Beck or Chapel-le-Dale, and the lower part of the valley of the Kingsdale Beck, more generally called Thornton Beck or the Doe, which unites at Ingleton with the Ingleton or Dale Beck.*

Between Chapel-le-Dale and Ribblesdale the ground rises to the isolated summit of Ingleborough, 2,373 feet above the sea. The highest point of Simon Fell is 2,125 feet.

In Ribblesdale below Horton, in Crummack Dale, below Chapel-le-Dale, and in the lower part of Thornton Beck, we

* We have already called attention to the mistake made on the Ordnance map of identifying the Dale Beck with the Doe, which really is the same as Thornton Beck.

find exposed the floor of old Silurian rocks (dipping at high angles and striking generally N.W. and S.E.) on which rests unconformably the mass of Carboniferous Limestone, Yoredale Rocks, and Millstone Grit of Ingleborough, Pennegent, and Whernside. The Carboniferous Rocks as a rule have very little dip; about Ingleborough it is generally N.E. at a low angle. There is one exception to this description, the mass of Carboniferous Limestone included between the two parallel Craven Faults near Ingleton having been bent into a rather steep arch (Figs. 1 and 3).

The Carboniferous Rocks may be grouped and described under the heads of Basement Beds, Carboniferous or Great Scar Limestone, Yoredale Rocks, and Millstone Grit. The following is a general section of the Carboniferous Beds around Ingleborough:—

Ingleborough.

		FEET.
Millstone Grit.	Coarse pebbly grit of Ingleborough summit	60
	Shales - - - - -	120
	MAIN LIMESTONE - - - - -	50-60
	Sandstone, with some shale - - - - -	200
	Shale, with some sandstone - - - - -	130
	Limestone (with shale) - - - - -	8-10
	Shale and sandstone - - - - -	60
Carboniferous Limestone Series.	MIDDLE LIMESTONE - - - - -	15-20
	Sandstone and shale - - - - -	150
	SIMONSTONE LIMESTONE - - - - -	25-30
	Sandstone and shale - - - - -	100
	HARDRAW SCAR LIMESTONE - - - - -	30-40
	Shales and limestone - - - - -	30
	GREAT SCAR LIMESTONE - - - - -	about 600
	BASEMENT BEDS, impersistent.	

The Basement Beds only occur as patches here and there between the limestone and Silurian Rocks (Fig. 3). In many places the pure limestone rests on the upturned jagged edges of the older rock, but often pebbles of quartz occur in the lower layers of the limestone, and sometimes a block of Silurian Grit is included. In a few places we find a considerable thickness of variable conglomerates and breccias, and the more important of these we will now describe. In Ribblesdale in only one place on the eastern side are these beds seen, viz., in a small stream between Brackenbottom and Dove Cote. The lower 10 feet of the limestone are thin-bedded, and contain bands of shale. Below these come about 20 feet of conglomerate of which the upper 5 feet are calcareous, the remainder consisting of red conglomerate or breccia. On the west side of the valley, 500 yards south of Bee Croft Hall, at the head of a small stream, 8 feet of limestone with quartz-pebbles lie on 11 feet of red conglomerate which rests on slate.

At Gillet Brae Head, 200 yards further south, we find the following section* :—

Gillet Brae Head, Ribblesdale.

		FEET.	
Carboniferous	{	Irregular concretionary earthy limestone -	3-4
		Light-grey calcareous shale -	2
		Calcareous conglomerate and breccia, with quartz and Silurian pebbles -	1
		Grey shale -	3
		Breccia, as above -	1
Silurian Rocks.			

West of Crummack there is a mass of probably not less than 20 to 25 feet of very coarse conglomerate at the base of a limestone-scar. In one place a large block of Silurian Grit 13 feet long is seen, but the coarse conglomerate dies out eastwards as a wedge between the lower beds of the limestone. At Austwick Beck Head the lower beds of limestone contain quartz-pebbles.

We see these beds at several places in Chapel-le-Dale. On the east side of the dale, in the first little stream below God's Bridge (close to the height marked 803 in the road), a section shows calcareous conglomerate resting on slate. In several other places 1 to 1½ feet of breccia forms the base of the limestone-series, and just east of the point in the road marked 811, at one of the numerous springs which rise in the limestone, coarse breccia rests on 4 feet of flaggy and shaly limestone with fossils, while pebbles of quartz and of Silurian Grit occur at the base of the limestone near Skirwith. On the west side of the dale a good section at a stream-head north of Twisleton Dale House exposes 8 to 10 feet of irregular conglomerate and some thin grey flag-bands. About 150 yards further westward brecciated conglomerate and dark-grey limestone with corals occur in alternations of 8 inches to 2 feet thickness. A little further on again are large pebbles or blocks of Silurian slate in the base of the limestone, while in several places dark-grey limestone with lines of quartz-pebbles occurs at the base. North of Dale Barn breccia reappears in a band of 2 to 3 feet thickness. The beds are well seen at Thornton Force where they have been described by Phillips and Sedgwick. Limestone forms the top of the Force and below is found—

Thornton Force.

		FEET.
Conglomerate, with pebbles chiefly of Silurian		
Rocks -	-	3
Conglomerate, very coarse, with pebbles 2 feet		
long -	-	1 to 2

* This seems to be the section described by Phillips. *Geol. of Yorksh.*, vol. ii. p. 15. It is also described by Mr. J. E. Marr in the Excursion Notes of the International Geological Congress, 1888.

Further down on the west side of the beck and above the slate-quarry we see—

Thin-bedded grey limestone passing down into
Thin grey limestone with quartz-pebbles, passing into
Loose conglomerate chiefly of quartz-pebbles and fragments
of Silurian Rocks with several lenticular nodules of
limestone.

Silurian Green Slate.

It is evident that these beds were deposited upon an uneven floor of the Silurian Rocks, for the line dividing the two formations runs sharply up or down 20 or 30 feet in places, while the bedding of the limestone keeps nearly horizontal. In other places, as south of Dale House, Silurian Grit sticks up in a boss, against the west side of which limestone has been laid down in horizontal strata. At Twisleton Dale House, too, the limestone and Basement Beds have been deposited against a boss of the old rocks. There is a marked example of overlap of this kind in the Carboniferous Limestone of Moughton Scar, above Capple Bank in Crummack Dale, which is best seen when looked at from a distance to the westward. In this case, though the limestone in the scar above is nearly horizontal, its base-line runs down as much as 150 feet in about 300 yards. Another case of the same kind almost as marked occurs at the Moughton Scars on the south side of the head of Moughton Lane. These examples show that little reliance can be placed on dips of small amount in the lower Carboniferous strata.

The earliest mention of the marked unconformity which exists in this district between the Carboniferous and Silurian rocks occurs in a book published at the beginning of the century by Playfair in illustration of Hutton's Theory of the Earth, and the account is so lucid that it is worth while to give his description in his own words:—

“I shall mention only one other, which was discovered by Lord Webb Seymour and myself, at the foot of the high mountain of Ingleborough, in Yorkshire. As we went along the Askrig road from Ingleton, about a mile and a half from the latter, an opening appeared in the side of the hill, on the right, about one hundred yards from the road, formed by a large stone, which lay horizontally and was supported by two others, standing upright. On going up to the spot, we found it was the mouth of a small cave, the stone lying horizontally being part of a limestone bed, and the two upright stones vertical plates of a primary argillaceous schistus. The limestone bed which formed the roof of the cave was nearly horizontal, declining to the south-east; the schistus, nearly vertical, stretching from north-west by west to south-east by east. The schistus though close in contact with the limestone seemed to contain nothing calcareous, and did not effervesce with acids in the slightest degree.”

“At the spot just described no breccia appeared to be interposed between the primitive and secondary rock; but we found a breccia at another point of the same junction, not far distant.

This was at a cascade in the river Greata, called Thornton Force, about two miles and a half from the place just mentioned. The Greata here precipitates itself from a horizontal rock of limestone, and after a fall of about eighteen or twenty feet, is received into a bason which it has worked out in the primary schistus. This schistus is in beds almost perpendicular; it exactly resembles that which has just been described, and stretches nearly in the same direction. On the south side of the river a breccia was seen, lying upon the schistus, or rather it might be said that the lowest beds of limestone contained in them many rounded fragments of stone, which on comparison resembled exactly the schistus underneath. The primary rock itself is here seven or eight hundred feet above the level of the sea. The same schistus, somewhat lower down the valley, and nearer to Ingleton, appears in large quantities and is quarried for slate. Here, however, the immediate junction of the limestone and schistus does not appear."*

The Great Scar Limestone is a nearly solid mass of greyish or light-blue limestone with but few partings of clay or shale, except near its base as described above, and occasionally near its upper boundary. But thin beds of shale do sometimes appear in the main mass of the limestone. One of greenish clayey shale occurs in the large quarries on the west side of the Settle and Carlisle Railway, south-east of Ribbleshead station. Its dip is lowering it gradually northward, and it probably is identical with the bed of shale which appears at a spring above the road to Gearstones near the Station Inn. Another thin bed of shale occurs in Gauber High Pasture Rocks, but this must lie at a somewhat higher horizon. As a rule, however, the limestone here seems fairly compact and homogeneous.

The Great Scar Limestone attains its highest point above the sea (about 1,500 feet) on the south-west side of Ingleborough, near Newby Moss, whence it falls to about 1,200 feet at Souther-scales Fell and South House Moor in a distance of nearly three miles, which equals a fall of 100 feet per mile or 1 in 53 nearly, not much more than a dip of 1° on the average, but in places of course the dip becomes steeper. North of Black Shiver Moss it amounts to 4° - 5° to the E.N.E., and it is more than the average about Hurnel Moss. The base of the Carboniferous Series lies at an elevation of 725 feet at God's Bridge and Thornton Force, nor in Chapel-le-Dale does it anywhere rise more than 150 feet above this, but in Ribblesdale and Crummack it is more variable in height. In Crummack on both sides of the dale it reaches to 1,175 or 1,200 feet and falls to 925 feet at Austwick Beck Head and much lower in the map to the south. The Great Scar Limestone must be as much as 600 feet thick on the average. Its base at Dowgill near Horton-in-Ribblesdale runs at 800 feet and its upper line at about 1,400 feet elevation. We get much the same

* Playfair's Illustrations of the Huttonian Theory, pp. 217, 218, 219; 1802.

result (about 625 feet) if we measure from its base in Jenkin Beck to its top above Crina Bottom, west of Ingleborough. The limestone forms a magnificent set of grey and white scars and rocky terraces on either side of Chapel-le-Dale, rising tier above tier from near the bottom of the valley. The highest limestone in the hill-side spreads out into a wide plateau, in places fantastically weathered by atmospheric agencies, especially along the numerous lines of joints.

Ingleborough is noteworthy for the great flats of bare limestone around its flanks, which are much fissured by joints. The joints appear principally to run N. and S., or N.W. and W.S.W. Good examples of this may be seen in Gauber High Pasture. The bare limestone, where the Drift has long been removed, has been much worn by the solvent action of rain containing Carbonic Acid Gas or vegetable matter, and worn into deep hollows, which generally end at the joints. Each block of limestone bounded by joints, has a little system of valleys of its own produced in this way. Where the rock is only just emerging by denudation from overlying shale or Drift it has usually a plane surface, but the further we go from this the more do we find the above-mentioned furrows developed. The joints, further, are much widened by the flow of water down their sides, and extend many of them to a considerable depth. Ferns and other plants, sometimes small hazel-bushes, grow in their sides in sheltered seclusion. Specially remarkable is the series of parallel N.N.W. joints on Moughton, some of which, enlarged by atmospheric causes, run in straight lines as fissures for a quarter of a mile or so.

On Simon Fell above the Great Scar Limestone occur several limestones in shales, which perhaps should be included with it, but lithologically they belong properly to the alternating series above it. These are from the Hardraw Scar Limestone downwards. At the north end of the northern spur of Ingleborough there are at least three, but the lowest amalgamates with the main mass a mile to the south. At the north end it makes a wide spread owing to its lying flat. The next shows up well (15 feet or more) on the north and west as far as Fenwick Lot, where it splits into two, but, owing to the Drift coming on thickly here, we were unable to trace it any further. Nor has it been detected in the ground to the south. On the east side it is not seen from above Colt Park to the south end of Park Fell, but a thin limestone is visible here which may be the same. It is generally of dark colour.

Next above, with an interval of shales, is the Hardraw Scar Limestone. This is of the usual character, dark, bituminous, with much black chert. On the north and west this must be nearly 30 feet thick. It is lost for a good part of the way under Drift-deposits. In other parts it gives a well-defined line of pot-holes on its upper surface.

These limestones with interbedded shales are about 90 feet thick. The series, from the main mass on the plateau of Park

Fell to its top, is about 650 feet thick, leaving about 560 feet for the portion of the true Yoredale Series represented here.

Above the Hardraw Scar Limestone are two well-marked limestones. The top of the lower, probably the "Simonstone," is about 200 feet above the main mass and that of the upper about 350 feet from it. Below the upper, two thin limestones besides may be seen in the upper part of Shiver Spring, a little gill which runs down near Rigg Barn, a cowshed about one third of a mile south of Colt Park. This is one of the best sections, but others may be seen at the north end, and also in one of the gills running down on the west side.

Sandstones occur in several parts of the series, but notably as follows. A large outlier with a flaggy base on the top of the hill. A coal-crop has been marked below this at the north end, by Prof. T. McK. Hughes, but this cannot now be seen nor at the S.W. base of the outlier. At this place there have been some workings of some kind, but they seem to have been made in the flaggy base with the object of getting flags or "throughs" for walling, and no trace of coal was here visible.

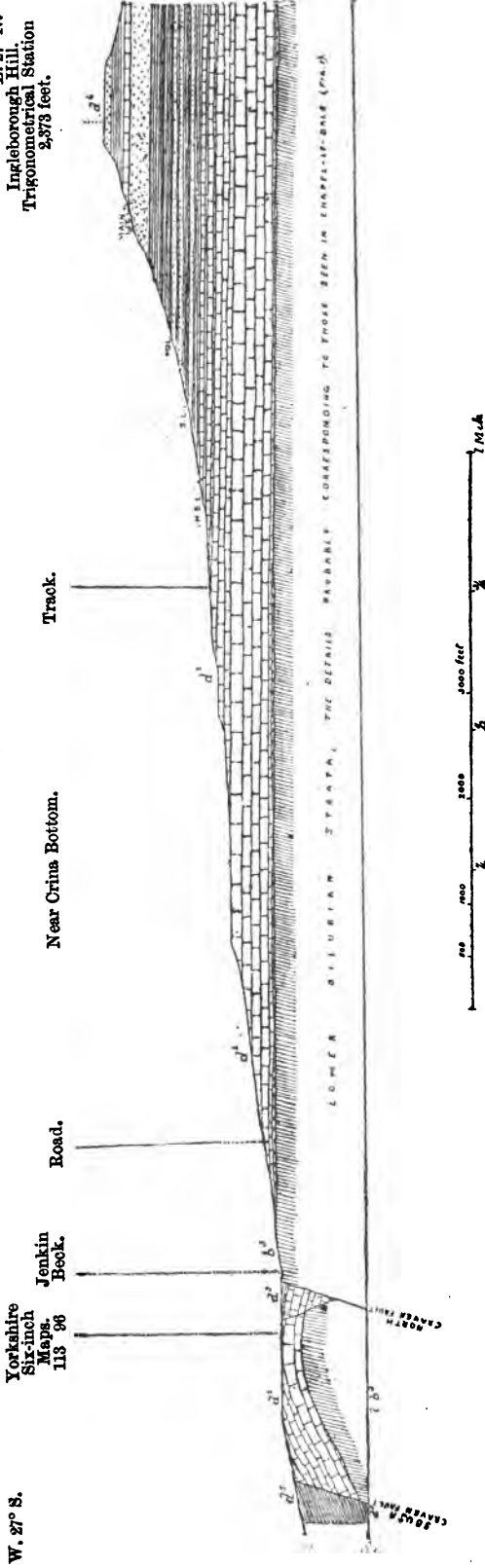
A sandstone-quarry also occurs at the north end, at a place erroneously marked "Limestone Quarry" on the Six-inch Ordinance Sheet. This lies some height above the Hardraw Scar Limestone. It has a bed of shales above it, and then another sandstone occurs which runs up to the base of the Simonstone Limestone.

All the Yoredale limestones below the Five-Yards Limestone can be well traced east of Simon Fell, but little is to be seen of any of them on the north side of Ingleborough, except the Hardraw Scar Limestone. This is fairly well seen in Meregill, and forms Black Shiver Ridge. At Tatham Wife Hole it is thrown up to the south about its own thickness, say 40 feet, by a fault running E.S.E to the nick above Foals Foot, where we find the fault split into several branches. The most northerly throws down north three to four feet, and the main branch, 15 to 20 yards further south, throws down south fifteen feet. The fault splits again higher up, the north branch keeping the main throw of 10 to 12 feet down south. The top of the Middle Limestone is seen at Black Shiver, viz., about six feet of limestone, grey in colour and weathering rather creamy, above which comes shale 10 feet, and then grit 20 feet, blocky in the upper part, shale 30 feet, and then traces of limestone. From this point there is a good clear section up a precipice to the top of the Main Limestone.

Southward from Tatham Wife Hole, and in fact all around the south side of Ingleborough and Simon Fell, and in the valley of Fell Beck, very little is seen of the lower Yoredale limestones owing to thick masses of Drift, and it has not been thought advisable to continue the lines all around the hill. South-west from the long southern shoulder of Ingleborough, near a place called Knoutberry Hole, two limestones crop out, the lower one probably being the Simonstone which runs along under the Cloven Stone. At Knoutberry Hole itself we find what may be the

FIG. 3.
Section from the Ingleton Coal-Field across the Craven Faults and through Ingleborough Hill.

By A. STRAHAN.



- d⁵. Coal Measures.
- d⁴. Millstone Grit.
- d³. Yoredale Rocks {
 - Main Lst. = the Main Limestone.
 - M. L. = the Middle Limestone.
 - S. L. = the Simonstone Limestone.
 - H.S.L. = the Hardraw Scar Limestone.
 - d². The Great Scar Limestone.
- d². Coniston Limestone.

Middle Limestone. It seems, however, to be only 5 feet or 6 feet thick at most, and to be not more than 60 feet above the Simonstone, so that if we are right about the identification, there is most likely a fault between them, these two being 150 feet apart, on the west side of the Fell Beck. The Hardraw Scar Limestone is partly exposed in Gaping Gill, as is also a thin limestone which comes between it and the Great Scar Limestone.

The thin limestone (8 to 10 feet thick) next above the Middle Limestone is probably the equivalent of the "Fossil Lime" of Wensleydale, the "Horseshoe" of Garsdale, and the "Five-Yards" of Teesdale. It is not very well seen, except in a stream that runs from the north side of Ingleborough and in one on the east side of Simon Fell. North of Ingleborough the upper part is dark and shelly, and the lower two or three feet impure limestone, turning to rotten-stone, with shale in the middle.

Above this thin limestone comes a mass of sandstone and shale, nearly 350 feet thick, of which the upper 200 feet are mostly sandstone and the lower part mostly shale. This 200-foot sandstone-band is a marked feature all around the shoulders of Ingleborough and Simon Fell, except at the head of Clapham Bents, where it is obscured by Drift and tumble. It is coarse and massive in places. The upper five to six feet are rather fine and blocky, and calcareous at the top, passing up into the Main Limestone.

There is thus no trace of the Underset Limestone about Ingleborough, nor any, as far as seen, of the little limestone which comes in Wensleydale above the Preston Grit and is called in Teesdale the Three-Yards Limestone. In fact as we shall see later on, the Underset Limestone has become so thin on the flanks of Whernside that it has doubtless thinned out altogether before getting to Ingleborough. The Main Limestone forms bands round Ingleborough and Simon Fell, in places a good deal obscured by tumbled rock and peat. It is best seen in the scar on the north side of Ingleborough. On the eastern side of Simon Fell it is markedly and coarsely encrinital.

Ribblesdale.

At the head of Ribblesdale the Great Scar Limestone is seen along Thorn Gill below Gearstones, and as far north as Low Brig on the Lancaster and Richmond high-road.

The overlying shales crop out above "Intack"* in Gale Gill and in a neighbouring sike. Limestone is seen over these shales at Low Gate and at Winshaw. The shales overlying this limestone appear in Hazel Gill and over them a sandstone. Over the sandstone comes the Simonstone Limestone, seen in Hazel and Gate Gills and in the neighbouring gills. The overlying shales are well exposed in the same gills, as also in Ouster Gill, where a thin limestone, three feet thick, lying on sandstone, appears in these

* So spelt on the Ordnance Map. The correct spelling is Intak.

shales. This thin limestone is again visible in the main beck below Newby Head, not far from the twenty-seventh milestone. Over these shales comes the Middle Limestone. This rock crops out above the limekiln on Black Rake, and in Gate and Winshaw Gills, and over it alternations of sandstone and shale in the same gills and also in Dry Gill.

The course of the above-mentioned beds round the side of Blea Moor to Littledale Beck is hidden by thick Drift, but the gills descending into Littledale from Whernside give good sections, particularly that called Coal Gill, where we see the following sequence of beds :—

Eastern Slopes of the Southern End of Whernside.

CARBONIFEROUS LIMESTONE SERIES :—

	FEET.
Shale - - - - -	8
Sandstone and shale - - - - -	48
MAIN LIMESTONE, of Greensett Crag, Hagg Worm Haw, and Craven Wold - - - - -	about 50
Sandstone and shale - - - - -	}
Coal - - - - -	
Shale - - - - -	
Grit, of Horsing Stones - - - - -	
Plate - - - - -	
UNDERSSET LIMESTONE, seen in Combe Scar (7½ feet), beneath Horsing Stones, and in Coal Gill (25 feet)	
Sandstone - - - - -	
Plate with a thin limestone - - - - -	
Sandstone and shale - - - - -	
Thin limestone - - - - -	
Sandstone - - - - -	
Shale - - - - -	
Thin limestone - - - - -	
MIDDLE LIMESTONE, at the High Force - - - - -	about 40
Sandstone - - - - -	}
Shale - - - - -	
Thin limestone, adhering to - - - - -	
Sandstone, at the Low Force - - - - -	about 120
Shale - - - - -	}
SIMONSTONE LIMESTONE - - - - -	
Sandstone - - - - -	about 20
Shale - - - - -	}
Thin limestone - - - - -	
Sandstone - - - - -	
Chert and limestone - - - - -	
Irony shale and plate - - - - -	
Limestone - - - - -	
Shale - - - - -	about 160 to 175
GREAT SCAR LIMESTONE.	

Of the above beds, the Simonstone Limestone and the beds below it are not clear ; but the beds above are well seen on the whole. The Underset Limestone in Coal Gill is about 25 feet thick ; but it thins southward, so that under Combe Scar, two miles from Coal Gill, it is only 7½ feet thick. The coal below the Main Limestone was once worked in Coal Gill and along the flanks of Whernside.

A comparison of beck-sections on both sides of Gale Beck, as the upper part of the Ribble is called, gives the following series of beds:—

Gale Beck.

	FEET.
MAIN LIMESTONE, of High Wold	80 to 100
Sandstone	} about 100
Shale	
Sandstone	
Shale	
UNDERSSET LIMESTONE, of Great, Middle, and Little Wolds	50
Thin shale	} 250
Flags	
Shale	
Limestone	
Sandstone	
Shales with thin sandstones, of Shivery Gill, The Mares, and Lat Gill	} 30
MIDDLE LIMESTONE, in Mares Gill, and Black Rake	
Sandstone with a calcareous band	} about 145
Shale	
Limestone, 2 feet thick, in Hazel and Lat Gills	
Sandstone	
Shale, above Hazel Gill Barn	} 30
SIMONSTONE LIMESTONE, between the words "Lat" and "Gill," below Hazel Gill Barn, and above Gate Cote	
Sandstone	

Below the Underset Limestone of Little Wold there is a bed of calcareous sandstone and shale, containing *Fenestella*, some lamellibranchs, and other fossils. This calcareous band appears as a black fossiliferous limestone with *Productus latissimus*, overlying shale with calcareous bands at Groove Head.

On the east side of Ribblesdale it is well nigh impossible to trace the sub-divisions that occur near the top of the Carboniferous Limestone Series under the great masses of Drift which conceal the beds. In the gills descending from Cam Fell the lowest bed seen is the sandstone below the Simonstone Limestone: but south of Cam Road we get a section in shale overlying limestone in Crutchin Gill; this is probably the shale below the Hardraw Scar Limestone.

Ling Gill gives a section in solid beds of Great Scar Limestone, and over it we have near Far House Barn the following descending section:—

Far House Barn, Cam Beck.

	FEET.
Sandstone	} nearly 25
Shale	
Limestone, with <i>Cauda Galli</i>	
Shale	
Coralline Limestone	
Shale	
Limestone	
Shale	
GREAT SCAR LIMESTONE	

In Cam Beck a limestone with corals and *Productus giganteus*, answering to the Hardraw Scar Limestone, is seen; but the subdivisions above are not visible. A little further south, on Old Ing Moor, we get ferruginous shale over the Great Scar Limestone, with a little brown impure limestone containing corals and *Productus*. Still further south, by a comparison of beck-sections, we get the following series of beds:—

South of Old Ing.

	FEET.
MAIN LIMESTONE, of Greenfield or Cush Knotts; more than	50
Gap—strata not seen	
LIMESTONE (? the Underset), at Cush Knott Well	
Gap	
Shale	nearly 100
Thin Limestone	
Shale	2
Thin limestone	
Sandstone or sandstone and shale	
Thin limestone, in one spot only six inches thick	
Platy shale	
Limestone, in one spot 2 feet	about 70
Plate	
Thin limestone	
Shale	
Sandstone	
Shale	
MIDDLE LIMESTONE	
Sandstone	
Shale	about 120
Sandstone	
Shale	
Limestone	
Sandstone	6
Shale	nearly 50
SIMONSTONE LIMESTONE	nearly 50
Sandstone	
Limestone, thin	
Sandstone	
Plate	nearly 100
Limestone, six inches	
Shale	
Cherty limestone, probably the Hardraw Scar	about 30
Ferruginous shale	about 25
Productal and coralline limestone.	
Plate, thin.	
GREAT SCAR LIMESTONE.	

Kingsdale.

In Kingsdale, on the western side of Whernside, we have the following sections; viz., in Gazegill due east of Kingsdale House, and in Buck Beck and Standing Gill.

Buck Beck and Gazegill.

- Sandstone, at Buck Beck Head.
- Shale.
- (Middle Limestone, not seen.)
- Gap—strata not seen.

	FEET.
Shale	} 110
SIMONSTONE LIMESTONE	
Sandstone	
Limestone	
Thick sandstone, at the highest waterfalls	} 40
HARDRAW SCAR LIMESTONE, at Gazegill Bank	
Shale	} about 50
Sandstone	
Shale	
Calcareous sandstone	
Shale	
Limestone.	
Thin shale.	
Limestone, at the lowest waterfall.	

The limestones below the "Hardraw Scar" are seen for some way up Long Gill, and then the sandstone below it crops out E.N.E. of "B. M. 1270." The Hardraw Scar Limestone appears at the junction of Swere and Long Gills, with a sandstone 13 feet thick over it forming a scar. The beds above are shown in the following section:—

Long Gill.

	FEET.
SIMONSTONE LIMESTONE	seen to 8
Sandstone	-
Gap	-
Sandstone	10
Limestone	3
Plate	7
Sandstone	13

Above the "Simonstone" we have shale; sandstone; limestone $1\frac{1}{2}$ feet; sandstone 3 feet; limestone $3\frac{1}{2}$ feet; shale; sandstone at the waterfall near "B. M. 1415"; the Middle Limestone; and over this in Swere Gill shale; sandstone; shale; a thin limestone; shale probably; sandstone; shale; sandstone at the 1600-foot contour-line, with a calcareous top; shale; sandstone at High Pike Quarry; the Underset Limestone of High Pike.

If we now descend the parallel gill, called Back Gill, we have a thin limestone answering to the calcareous top of the sandstone in Swere Gill; the sandstone is not seen; but the underlying shales are well exposed in scars at Back Gill Head; and below them a thin sandstone answering to a bed in Swere Gill; and a little lower down we come to the Middle Limestone, which does not appear again southward till we get to Yordas Gill. Below the Middle Limestone we have, as shown in several gills descending from Graygarth Fell, the following section:—

Graygarth Fell, the eastern slopes.

Sandstone and shale.
Thin limestone, seen in Yordas Gill, and at Bakstone Gill Head, and at Cluttering Gill Head.
Sandstone.
Shale, seen at the gill-heads.
SIMONSTONE LIMESTONE.
Sandstone.

	FEET.
Limestone	3
Sandstone	1
Limestone	4½
Shale	6
Limestone	3
Sandstone	8
Shale.	
Limestone.	
Shale	
HARDRAW SCAR LIMESTONE.	8 to 10
Limestone	25
Shale	2
Limestone	3
Sandstone	
Shale	
Sandstone	
Shale	} about 40
GREAT SCAR LIMESTONE.	} seen to about 140
Limestone	
Sandstone	
Limestone	
Plate	
Limestone	

Between the Middle and Underset Limestones we have but poor sections on Graygarth; but the Underset is seen in several spots with its basement-sandstone, and over it shales; and over these a bed of grit or sandstone; then shale or sandstone with a seam of coal; and then the Main Limestone at the 2000-foot contour-line; and over it shale and then sandstone forming Green Hill.

A section plotted at the south end of Whernside gives the following thicknesses:—

Western slopes of the Southern End of Whernside.

	FEET.
UNDERSSET LIMESTONE, thin but making swallow-holes	-
Measures, mostly shale	200
Thin limestone and shale	15
Measures with thick sandstone, forming Great and Little Hard Pots	130
MIDDLE LIMESTONE, not less than	30
Measures; sandstone in the upper part	110
SIMONSTONE LIMESTONE, cherty	-
Measures; nowhere exposed	80
HARDRAW SCAR LIMESTONE, cherty, sometimes in two beds	75
Shale	30
Thin limestone, not always separable from the Great Scar	
Limestone	
Shale	
Great Scar Limestone	470

THE CAVES.

By R. H. TIDDEMAN.

The numerous caves and "pots" which occur in the Carboniferous Limestone give it an exceptional interest and they are far more common in this district than in most. The neighbourhood of

Ingleborough presents examples of this kind of underground erosion which are second to none in the Kingdom for numbers, extent, and interest. Their abundance here is probably due to several causes:—

- 1st. The large horizontal flats of bare limestone which give the water every chance of finding an entrance.
- 2nd. The numerous vertical and long continuous joints which so easily lend themselves to water-carriage.
- 3rd. The rarity of beds of shale or other alternations in the great body of the limestone which would tend to check the free passage of water.
- 4th. The rapid descent of the ground beyond the limestone-plateaux which gives steep gradients to the water-flow in the limestone.
- 5th. The height of the Fells above, which form condensers to atmospheric vapour and give a rainfall above the average.

Gatekirk Cave.—About a mile from the “Hawes” or watershed between the Ribble and the Lune the Dale Beck loses itself, except when in flood, in fissures in the limestone, at a part called on the six-inch map Ivescar End Moss. The river, as in many other places, sinks higher up or lower down its course according to the quantity of water running at the time, and the cracks in its course which can accommodate it. For some distance the river-bed in ordinary times is dry, and the water emerges again from a tunnel-like cave facing down stream. It will be seen that this cave forms a short cut underground for the stream, and in the Alluvium to the north is a series of holes in a straight line all indirectly connected with it. A small hole, somewhat like an old quarry, occurs at Philpin, lower down the stream. It is choked up with mud and rubbish, but is evidently connected with the subterranean system of drainage which we are now about to describe.

Weathercote Cave, a large “pot” or cave, whose roof has fallen in, includes two large pits, which, though connected below, are separated above by a natural arch of limestone. The descent is made by steps for a good part of the way and then by rocks and fallen débris under this arch. Opposite, the stream, which has lost itself through fissures in its bed higher up, emerges from beneath a cliff and falls through the rest of the descent in a beautiful “force,”* 75 feet in depth. At its bottom the stream runs off to the left in a tunnel-shaped cave. This passes by two other “pots” yet to be described.

Jingle Pot, which lies 125 yards lower down, is a large chasm in the overflow-channel of the stream under the right bank. A small heap of coarse gravel may usually be seen on its lower or downstream edge. This has been brought from the depths by the

* A watercolour sketch of this beautiful scene by J. M. W. Turner was in the possession of the late Colonel Lyell, brother of Sir Charles Lyell.

great rush of water upwards, at the last great flood. The size of the stones and the depth of the shaft up which they have been carried vertically give one a great idea of the force of the water under these circumstances.

Hurtle Pot.—At a further distance down stream of 200 yards, but high up on the right bank, is another large pot, evidently connected with the underground stream-course. On entering it, by a small cleft at its lower edge, one sees a steep slope of river-mud and rubbish, which leads down to a dark pool of still water, surrounded on all other sides by limestone-cliffs. When the water is agitated by throwing in a large stone it “hurtles” against the enlarged fissures of the limestone and produces a curious sound; hence its name.*

The river gradually rises again in its bed, but a short distance below Chapel-le-Dale the limestone forms a natural bridge across the channel, allowing the water to pass through crevices in it and giving a dry transit to men and cattle above. This goes by the name of “God’s Bridge.”

In all these underground courses it sometimes happens that the channels are not sufficient to carry off all or even the greater part of the drainage of the area. Even Weathercote Cave is filled to the brim, so that the water runs down the old open-air channel, and it is on such occasions as these that it boils up through Jingle Pot and lifts the accumulation of gravel already referred to. Hurtle Pot also shows, by the accumulation of mud on its sides, that it is sometimes brim-full.

Douk Cave lies 800 yards S. 35° W. from the Hill Inn, and is an interesting example of an underground stream whose roof has fallen in through a part of its course. It forms a rude oval, and is surrounded on three sides by steep cliffs, especially on the east, but on the west it may be easily approached. The stream runs out of a cave on the east side, and loses itself under debris at the west end. A small fault, with a downthrow of 3 feet to the north, coincides with the stream. The cave is accessible, and at a distance of about 80 yards up stream opens out overhead into a deep natural shaft, where light may be seen. This pot is called Little Douk Cave on the six-inch map. At the surface the stream may be heard running down below.

Braithwaite Wife Hole is a smaller broad pot about 900 yards to the S.S.W. from Douk Cave. It shows a section of Glacial Drift (clay and gravel) to a depth of about 20 feet, and about 40 feet of limestone below. At the junction between the two, on the S.E. side of the pot, were to be seen glacial striæ, indicating ice-movement in a south-westerly direction. Numerous other smaller pots occur over the limestone, and more particularly along the line where the shales rest upon the main mass of the Great Scar Limestone, but they do not call for any special remarks.

* An old writer in “A Tour to the Caves in the Environs of Ingleborough and Settle,” etc., 2nd Edition, 1781, p. 23, states that here “large black trouts are frequently caught in the night by the inhabitants.”

*Hellan Pot, or Alax Pot.**—This, though not the deepest of the great natural shafts occurring in the Limestone of Craven, is on the whole perhaps the most striking. It lies on the limestone-plateau on the east side of Simon Fell, and about half a mile west from Selside.

As with many more of the large "pots," a well-marked dry valley, the earlier channel of the stream before it found its way down into the joints and gradually excavated for itself an underground course, leads up to the mouth of the abyss down which the stream now plunges. The shaft is 216 feet in depth, but has a great width, and an open mouth, so that it is well lighted up, and one can peer well down into the recesses. The sides and ledges on the way for some distance are well clothed with ferns, mosses, and a few little shrubs, and it forms a scene of weird grandeur.

This pot was explored in 1870 by Mr. Birkbeck, of Anley, near Settle. A great mass of gravel lay at the bottom, and the stream ran off by a cave on the north side. This was followed for some distance. It had a tortuous course, and opened out in places into considerable chambers; and in one or two places descended in cascades to lower levels. Further the party was stopped by a deep eddying pool, which cut off all further advance. In all particulars it was similar to other water-caves nearer the surface, except perhaps in size. Mr. Birkbeck was much struck by the exceedingly sharp flutings of the limestone-sides of the shaft near the bottom. They ran vertically, and with great regularity. They were evidently cut out by the force of the water dripping from so great a height and unaffected by any side-winds in its course. Similar sharp flutings occur in pot-holes on Nateby Moor, near Kirkby Stephen, in Westmoreland, in the Main Limestone.

Long Churn and Dickon Pot.—These are respectively the upper and lower portions of a tributary passage to Hellan Pot, with an entrance midway about one hundred yards away from that chasm. It has been followed 241 yards westwards to daylight, and to near its termination in Hellan Pot eastwards.†

Gaping Gill and Ingleborough Cave.—It is impossible to dissociate these two. The first is the entrance, the second the exit of the same stream. Gaping Gill collects the drainage of rather over a square mile of high ground in the south-east angle between Ingleborough and Simon Fell. In a continuance of dry weather the stream is insignificant, but after an unusually heavy rainfall its force is tremendous. The moderately steep gradient of the channel above Gaping Gill adds intensity to its action, and the shoals of coarse gravel, consisting of boulders whose individual weight may be better reckoned in tons than in

* Allum Pot on the Six-inch Ordnance Map.

† The exploration of this cave is described in "A Tour to the Caves in the Environs of Ingleborough and Settle," etc. 2nd Edition, 1781, p. 44. This descent was also made by Mr. Birkbeck and Mr. W. Metcalf in 1847 and 1848. See Cave Hunting, W. Boyd Dawkins, p. 43.

pounds, give a good idea of its occasional strength. At present the pot-hole will intercept any flood that comes down, but before its capacity was so great, the stream must have run on past the present hole along a valley which may still be easily followed, and which forms the best guide whereby to find Gaping Gill when advancing on it from the lower ground. This dry old stream-bed runs past two other "pots," or fallen-in caves, by Trowgill, and on past the present mouth of the cave, where the water again joins it. The brook continues through the grounds of Ingleborough House by the pretty village of Clapham, and onwards to the Lune. Gaping Gill has not so wide a mouth as Hellan Pot, nor is it so wide generally, though it is quite possible that it expands in places in its long descent. At the surface it is somewhat funnel-shaped, and the stream enters it on the north side, falling over a horizontal ledge of bare limestone. The side of the shaft opposite the entrance of the stream has been much battered by large boulders, brought down by the water in heavy flood. This was markedly the case, many fresh fractures being seen, after a notably heavy thunderstorm in the summer of 1872. Mr. Birkbeck made an attempt to descend this gill, and succeeded in getting on to a ledge a good way down, but could not get further. Under the right bank of the stream, a few feet from its fall, behind a fallen block of limestone, entrance may be obtained, by crawling, into a small cave. It opens out a little on entering, and then in a very short distance plunges down into the abyss—a depth of 360 feet. It is most dangerous to visit this place without a light.

There is a generally received opinion that the stream which enters at Gaping Gill is the same as that which has an exit beneath and sometimes through the Ingleborough Cave. The ground for determining this is narrowed by the North Craven Fault which crosses to the S.E. near the head of Clapham Tarn. This forms a barrier of Silurian Rocks crossing the valley, and all springs from the drainage of the valley above must come out at this (it being impervious to water) if they do not come out before. No springs of sufficient size to dispose of the water which falls into Gaping Gill come out at this barrier or above it, if we except the stream coming out under the cave, and the volume of this in a general way varies with the quantity of water poured into Gaping Gill. The great size of the pot and the extent of the cave both point in the same direction.

Bar Pot is a shallow broad depression evidently caused by the falling in of the limestone from being undermined beneath. It lies a little to the right of the old stream-course as one descends towards the cave, on the top of the limestone-plateau. Trowgill, further down, is a narrow steep ravine at the edge of the same plateau. The narrowest part of the ravine shows on its sides hollows in the rock which look much as if they owed their origin to the action of a stream; but no stream can descend now, nor can have done so to any great extent since Gaping Gill was formed. Just above the south-east scarp of Trowgill is a huge hollow in the plateau, which must also be due to the underground

excavation by water. It is full of broken angular limestone, broken apparently by the rocks having given way and fallen into a pre-existing hollow or cave. The débris prevents ingress on any side, but a little excavation and exploration here might lead to a further knowledge of the extent of the Ingleborough Cave than we at present possess.

The Ingleborough Cave.—This cave has been described by Mr. J. W. Farrer* and Prof. J. Phillips,† who have both given plans of it. As regards its earlier history we learn that about the first 80 yards had been known from time immemorial. In the year 1837 a large curtain or dam of stalagmite, which barred further progress, was removed, and a large pool of water let off, so as to reveal the long series of chambers and galleries which are now visible. These stretched “first to the N. then to the N.W., afterwards to the N. and N.E., and finally to the E.,‡ till after two years spent in the interesting toil of discovery, at a distance of 702 yards from the mouth, the explorers rested from their labours in a large and lofty irregular grotto, in which they heard the sound of water falling in a still more advanced subterranean recess. It has been ascertained at no inconsiderable personal risk that this water falls into a deep pool or linn at a lower level, beyond which further progress appears to be impracticable.”§

The dam referred to consisted of travertine, compact on the outer side and more loosely grained on the inner surface. The outer slope is more gradual than the inner, which is very steep: this seems to be the rule with all the stalagmitic dams in the cavern. In many places shelves of stalagmite have grown out from the sides of the pools on the water-level. This has been caused no doubt by a greater evaporation of calcareous water at the line of junction with the rock.

On the roof near this dam are little fringes of stalactites which on reaching the water have expanded into a continuous body of calcareous matter, and this is now suspended by their slender attachments.

One point worthy of remark is that the outer side of the dams of stalagmite consists always of a compact, crystalline, clean deposit of spar. The inner side, which was deposited under still water, is more cellular or looser in texture, and takes on a branching coralloid or botryoidal form. It is, moreover, not so clean, and a deposit of mud often occurs between the little branches of spar. The cave, being subject to floods, and the deep pools behind the barriers forming basins of settlement for the mud, that and other impurities have interfered with the continuous deposit of tufa, and account for its irregular development. On the overflow side, on the contrary, the mud would be washed off by the first flow of clean water which succeeded the storm-waters.

* *Quart. Journ. Geol. Soc.*, vol. v. pp. 49–51, 1849.

† *Rivers, Mountains, and Sea-Coast of Yorkshire*, 1853, pp. 30–35, and Plate VII.

‡ The subterranean course of the cave is indicated by dotted lines on the Six-Inch Ordnance Map.

§ *Rivers, Mountains, and Sea-Coast of Yorkshire*, 1853, pp. 30, 31.

Thus in many places where water is now dripping from the roof on to surfaces which were formerly submerged in pools, the difference in colour and appearance of the later deposit is very marked, and its thickness may be used as a measure of the rate at which the spar is formed where the date of the destruction of the barrier is known.

The outer side of a stalagmite-dam consists of a series of innumerable little horizontal basins, with rather sharp edges, ranged one above another, not in horizontal planes with one another like brickwork, but more like irregular masonry. These little basins often contain small unattached aggregations of calcareous crystals, which grow from the gradual evaporation of the water in the basin in dry intervals.

The upper edge of a barrier is always horizontal, and necessarily so. Where the greatest flow of water occurs, there is the greatest deposit of calcium carbonate, and so the tendency is always towards the formation of a level edge. If a dam receives injury and the water-level is lowered, the stream passes through the gap and slowly builds it up again; meanwhile the rest of the edge remains at its existing level until the gap is restored and the outflow is again equally distributed. The level edge is far from running in a straight line across the cave, but often lies in curves of great beauty.

Proceeding up the cave from the old barrier we gradually ascend to its water-level and soon arrive at the "Pillar Hall," so called from a large stalactite continuous from roof to floor. We have here another stalagmitic dam, and from this point onwards for some distance a kind of "dado" of tufa marks with great regularity the former level of the water. This pool apparently drained itself by enlarging the joints at the hole called "the abyss." Here and elsewhere in the cave the tufa has grown out in places into shelves at the surface of the former water-level. In the base of such shelves may often be seen large pebbles, now entirely supported by the calcareous cement. These remind us of a time when the cave was filled in with gravel to that height, and of its subsequent clearance by floods. Many of these shelves have had large additions made to them above, by water trickling out from crevices at higher levels, and large projecting bosses are the result. The so-called "Beehive" is one of them. Folds of tufa, resembling drapery, hang from them.

The roof of the cave lowers gradually, and you soon arrive at the first "creeping-place." Though low, it is broad, and the road has been cut partly through sand and gravel and also through rock. We emerge into the side of what is called the Long Gallery, which seems to coincide with a fissure: it is wide and lofty, terminating on the right in a large boss of stalagmite called the "Ladies Cushion." Reasoning by analogy we may suppose that this dams back a body of water, and probably if it were tapped, access might be had to a further branch of the cave. It is not, however, running in the direction of Gaping Gill, but rather back towards the cave-mouth.

Retracing our steps to the creeping-place, and passing by it, we come to a curious development of tufa. It has taken the form of a number of vertical plates attached to the right wall, which, on being gently struck with a stick, give forth musical notes, higher or lower according to their size. The largest, with a free end, gives a deep-toned note like a large muffled bell.

The "Long Gallery," which extends for about 200 yards, presents many diverse forms of stalagmites which are worthy of study. There are also good examples of limestone-weathering of different kinds. At its upper end this gallery forks out into two branches. That to the right, which seems to be the main branch, if followed a short distance, is found to be choked with river-gravel to the roof. The other conducts to the "Cellar-Gallery," a long, round-arched, and mostly low vault, with enlarged joints crossing it at frequent intervals. This part is subject to extraordinary floods, such as that in 1871, when it was so choked with mud and sand as to be nearly impassable.

The "Giants Hall," a more spacious chamber, though hardly justifying its name, has been the usual limit of exploration. Very rarely people have gone further down a crevice on the right side of it which leads to a shallow low-roofed stream-bed. There is only just room to creep, but in time it leads to a long deep pool with high roof and vertical sides. The late Mr. James Farrer and subsequently Mr. John Birkbeck, junr., both attempted to follow this, but without success. This is the limit of our knowledge of the cave in 1890.

Yordas Cave lies on the western side of Kingsdale at the foot of Greygarth. From a small entrance it "expands within to a large and lofty chamber (60 yards long and above 20 high), in which water dropping from the roof and sides has formed the numerous and fantastic stalactites and stalagmites. . . . Farther in, a circular chamber appears, its roof supported by spirally aggregated pillars of stalactite . . . in wet seasons a cascade adds its effect to this beautiful scene. This water is, no doubt, derived from the stream which, a little farther up the glen, is swallowed up by the limestone rock."*

* Rivers, Mountains, and Sea-Coast of Yorkshire, 1853, p. 26.

CHAPTER IV.—CARBONIFEROUS ROCKS—*continued.*

DISTRICT 2. DENT AND GARSDALE.

By A. STRAHAN.

THESE dales, both of which drain westward into the Lune, are divided from Chapel-le-Dale and the Ribble drainage-system by the great Millstone Grit-capped fells of Crag Fell and Whernside, and from Wensley Dale by Widdale Fell. They have been excavated for the most part in Yoredale Rocks, lying in their normal nearly horizontal position, but towards the west they cross the great boundary-fault which limits the Carboniferous Rocks from Leck Fell to near Kirkby Stephen. The map now under description includes a short length only of this fault, but affords opportunities of observing that the strata are not only thrown down to the east by it, but have been doubled sharply back along its whole eastern side, so as even to be inverted in places. The fault also hades to the west, so far as we can follow it down the sides of the gills, and therefore belongs to the class sometimes referred to as "reversed faults." This peculiarity and the sharp twist-up of the Carboniferous Rocks indicate that the displacement was accompanied by great lateral compression. The Silurian Rocks on the west side of the fault show the contortions and high dips usual to these strata, which of course resulted from pre-Carboniferous earth-movements, but here and there are overspread by nearly horizontal patches of Carboniferous Basement Beds. A portion of one such patch falls within the north-west corner of the map.

Carboniferous Basement Beds.

The deep-red conglomerate, of which this division of the Carboniferous group consists, lies in Hole Beck Gill on Coniston Flags, stained as usual by infiltration from the rock above. The pebbles, which compose the mass of the rock, range up to a foot in diameter, and are well-rounded. The fault here brings the conglomerate face to face with the upper beds of the Great Scar Limestone, a displacement of about 600 feet. The best exposures of the Basement Beds occur in the valleys of the Clough and Rawthey in Quarter-Sheet 97 N.W.

Great Scar Limestone.

This rock is laid bare for nearly the whole length of Dent, though it has not been reached in the bottom of Garsdale, partly through the latter being less deep, but more especially in consequence of a gentle dip, varying from north-west to north-east in

direction, through which the Great Scar Limestone falls from an elevation of about 1,100 feet in Kingsdale to 900 feet in the upper part, and 700 feet in the lower part of Deepdale, to 500 feet in Dent, and below the surface of the ground (721 feet above the sea at the Church) in Garsdale. In Dent the gradient of the river-bed frequently agrees with the inclination of the strata, and in such cases the water slides for many yards over the smooth surface of the same bedding-plane. But near the fault the limestone, traversed by innumerable cracks filled in with barytes, rears vertically up, as may be seen in the bed of the Dee, 200 yards west of Barth Bridge, and on the west side of Gawthrop. At the latter locality a small gill follows the actual line of fault, and shows shattered shales of the Coniston Limestone Series in its west, and Great Scar Limestone in its east bank. Thence the limestone runs southwards in a narrow strip through Cragg Wood, always nearly vertical, and with a strike parallel to the boundary-fault.

In Flinter Gill, Yellow Gill, Scotchergill, and Deepdale Head, one or two thin limestones lie a few feet above the top of the Great Scar Limestone:—

Flintergill, near Dent.

	FEET.
Shales and sandstone.	
Limestone - - - - -	3½
Sandstone - - - - -	9
Limestone - - - - -	3
Shale - - - - -	8
GREAT SCAR { Thin-bedded black limestone - -	3
LIMESTONE. { Hard grey limestone.	

Deepdale Head.

Limestone - - - - -	8
Shale and sandstone - - - - -	8
GREAT SCAR LIMESTONE.	

Near Dent Head a band of shale, six feet thick, separates the upper portion of the Great Scar Limestone from the main mass. This portion may represent the eight-foot limestone of Deepdale Head, though it is thicker, and more closely connected with the Great Scar Limestone. Through parts of its course the Dee traverses picturesque chasms or deep circular pools, such as Hell's Cauldron and Black Dub, which have been formed by the solvent action of the water on the rock.

At Hud's Force, about a mile higher up, the water falls over a ledge of hard limestone underlain by a shale six feet thick.

Yoredale Beds.

The Hardraw Scar Limestone is well exposed in the deep gills which run northwards to Gawthrop. Below it lie thick shales

and above it shales with bands of limestone, one of which is rich in corals. A section in Oliver Gill shows:—

Oliver Gill.

	FEET.
SIMONSTONE LIMESTONE.	
Sandstone.	
Limestone	3
Sandstone with calcareous bands	13
Limestone	5
Strata not seen	3
Sandstone	6
Shale	15
Black coralline limestone	3 $\frac{1}{2}$
Shale	5 $\frac{1}{2}$
Limestone	9
Shale	8
HARDRAW SCAR LIMESTONE, about	20

The same beds run with little change through Flinter Gill to Yellow Gill and How Gill, where they are partly cut out by faults. Gastack Beck Head (in Deepdale), gives the following details:—

Gastack Beck Head, Deepdale.

	FEET.
SIMONSTONE LIMESTONE, about	12
Sandstone	1 $\frac{1}{2}$
Shale	6
Sandstone	10
Sandy limestone	5
Sandstone with thin shale	12
Sandy limestone	$\frac{1}{2}$
Sandstone	11
Shale	7
Calcareous shale with fossils	1
Shale, about	8
HARDRAW SCAR LIMESTONE.	

The Simonstone Limestone, a black and homogeneous rock, has been quarried in Oliver Gill for "black marble." In this neighbourhood a thick soft shale, which has been deeply cut into by the streams, lies next above it.

In the upper part of Oliver Gill the Middle Limestone contains a thin band of shale in its upper part, about 2 feet of limestone being thus separated from the main bed, while the Five-Yard Limestone occurs at its usual distance above. This thin limestone may be traced along the dale for some miles, but the "Five-Yard" is not seen again as far as Force Gill, on the east side of Whernside, where it reappears in its usual position. The thin limestone below the Middle Limestone also appears in the gills near here, and in Flintergill Head a bed, about 1 $\frac{1}{2}$ feet thick, may represent

the Three-Yard Limestone. The section of the Middle Limestone in Gastack Beck runs as follows:—

Gastack Beck.

		FEET.
MIDDLE LIMESTONE	Limestone	2½
	Shale	6
	Limestone	18
	Sandstone.	

Along the east side of Deepdale the strata lie hidden under thick talus from the long and steep slopes of Whernside, though the various limestones make their presence known here and there by swallow-holes. They come into view again in Hacker Gill, the Hardraw Scar Limestone having a shale-band, 2 feet thick, near its base. The two thin limestones below the Simonstone, and the Simonstone itself with a thickness of 18 feet, also reappear. The upper part of the gill intersects the thick flags and sandstone which underlie the Middle Limestone, and shows that here as in Gastack Beck the top part of the Middle Limestone is separated from the main bed by a thin shale.

In Blake Beck the Hardraw Scar Limestone forms a remarkably picturesque waterfall, resembling in many ways the Hardraw Scar Force from which that rock takes its name. The ledge of the force is formed by the lower beds of limestone and the underlying sandstone while the chasm is excavated in the thick body of shale which separates this bed from the Great Scar Limestone. In the upper part of the beck the following section occurs:—

Blake Beck.

		FEET.
MIDDLE LIMESTONE.		
Sandstone	-	2
Shale	-	9
Sandstone	-	12
Shale	-	20
Limestone	-	1
Flags	-	56
Shale	-	25
SIMONSTONE LIMESTONE		18
Sandstone	-	9
Shale	-	6
Sandstone and flags	-	50
Shale with limestone (4½ feet)	-	12
Sandstone	-	18
Shale	-	10
HARDRAW SCAR LIMESTONE.		

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At Dent Head the Hardraw Scar Limestone also has been worked for "black marble," but the quarry is now occupied by the piers of the Midland Railway Viaduct. The Arten Gill Viaduct is supported on the same bed. The Simonstone Lime-

stone was quarried in Short Gill for the building-stone of the Dent Head Viaduct, and is exposed again in Fell-end Gill to a thickness of 17 feet. Its upper part and the thick shale over it crop out in the deep cutting at the south end of the Arden Gill Viaduct, while the thin limestone which occurs between the Simonstone and the Middle Limestones runs along the top of the cutting above Nell's Garth (Cow Dub) as shown below:—

Railway-cutting above Cow Dub.

	FEET.
Shale - - - - -	6
Limestone - - - - -	1
Sandstone - - - - -	4
Shale with thin sandstone - - - - -	25

A second thin band a few feet higher up occurs in the gill at the north end of the cutting, and again in Monkey-beck, where it is $1\frac{1}{2}$ feet thick. The Middle Limestone crosses this gill at the north end of the platform of Dent Station, but has slipped, so as to present the appearance of dipping steeply down the hill. Lower down the following section occurs:—

Monkey-beck.

	FEET.
Shale - - - - -	50
SIMONSTONE LIMESTONE - - - - -	16
Sandstone - - - - -	12
Limestone - - - - -	$2\frac{1}{2}$
Sandstone - - - - -	12
Limestone - - - - -	1

In Cowgill we see both the Three-Yard and the Five-Yard Limestones, the section of the latter being as follows:—

Cowgill.

	FEET.	
Five-Yard Limestone {	Red-topped Limestone - - - - -	$1\frac{1}{2}$
	Shale - - - - -	1
	Productal limestone - - - - -	$2\frac{1}{2}$

About 600 yards down the gill, we get the following section of the Middle Limestone:—

Cowgill.

	FEET.	
MIDDLE LIMESTONE {	Limestone.	
	Sandy limestone - - - - -	3
	Sandstone - - - - -	2
	Limestone - - - - -	5
	Sandstone - - - - -	6
	Limestone and calcareous sandstones - - - - -	3
	Shale.	

Along the north side of Dent this and the Five-Yard Limestone occur repeatedly as far as Hall Bank. The thick shale in which the latter lies has slipped in several places, leaving

hollows in the hill-side which become conspicuous when the sun is low. The sandstone below the Middle Limestone is flaggy and has been largely quarried for roofing near Scotchergill.

The Simonstone and Harddraw Scar Limestones are well exposed in Scotchergill, where the following section was taken :—

Scotchergill.

	FEET.
SIMONSTONE LIMESTONE, about	18
Sandstone with shale	25
Limestone with <i>Productus giganteus</i>	3
Sandstone	9
Shale	5
Sandy limestone	6
Sandstone	15
Shale	15
HARDDRAW SCAR LIMESTONE	25
Sandstone	5
Shale	60
Shale with bands of sandstone	12
Shale	40
Limestone	5
Calcareous sandstone and shale	18
GREAT SCAR LIMESTONE.	

West of the gill the limestones, after being lost to view under talus and Drift for about two miles, reappear in a gill near Hole House, near the point where the strata turn sharply up to the great fault. They may be traced hence by swallow-holes across the moor to the River Clough, where also they stand in a vertical position (Quarter-sheet 97 N.W.).

The Main and Underset Limestones occur as outliers round Dent, on the hills known as Rise Hill, Widdale Fell, Wold Fell, Blea Moor, Whernside, and Crag Fell. The exposures on the east end of Rise Hill will be presently referred to; on the south side of the hill we find but little evidence for fixing their position, but on Widdale Fell both rocks repeatedly appear, and on Pike's Edge a thin limestone, possibly the Little Limestone (see p. 19) is seen as below :—

Pike's Edge, Widdale Fell.

	FEET.
Shale (top not seen)	6+
Calcareous shale	2
Shale	3
Fine blue limestone, weathering yellow	$\frac{1}{2}$
Shale	1
Decomposed cherty limestone	1
Shale and gannister.	

Further south, near Cross Pits, a thin limestone lies close above the Main Limestone, the horizon of the cherty rock of Pike's Edge being marked by cherty bands in the shale above.

The coal between the Main and the Underset Limestones has been worked on this side of Widdale Fell also as far as the Cross

Pits Colliery. On Blea Moor there is a cap of coarse grit with a few small quartz-pebbles, probably the "seat" of this coal-seam, for the Underset Limestone occurs at the right distance beneath.

On Whernside, and especially on its north-east side, both the Main and Underset Limestones stand out conspicuously. The latter forms the Great Wold and runs, with the overlying calcareous shale, by the head of Blake Beck; it contains chert-nodules in its upper part, and reaches a thickness of 30 to 40 feet, though it dwindles away in Combe Scar to the south to about $7\frac{1}{2}$ feet. The Main Limestone forms the features known as Hagg Worm Haw and Greensett Crag. Above it lies a thick shale, without however any equivalent of the Little Limestone. The Cross Pits and Garsdale Pits coal has been worked on Whernside; also, in some old pits dotted at intervals for a long distance along the north and west sides of the hill, and near Combe Scar, where one of the levels still remains open. The same bed has been dug in Coal Gill (see also p. 29).

A small outlier of the Underset Limestone survives on High Pike; and the underlying sandstone is largely quarried for flags. A thin limestone lies over the flags in the quarry, and a calcareous encrinital shale with thin limestone occurs in a gill about 50 feet below, at about the horizon of the Three-Yard Limestone.

The Underset Limestone on Crag Fell yields encrinital "marble," the quarry showing the following section:—

Marble Quarry, Crag Fell.

	FEET.
Shale (top not seen) - - - - -	6+
Laminated cherty and calcareous shale with fossils - - -	2
Encrinital chert (silicified limestone) - - - - -	3
Encrinital limestone ("marble") about - - - - -	20

The Main Limestone is overlain by a thick mass of shale which has been deeply gashed by the streams from above. A thin limestone (perhaps the Little Limestone) occurs here and there near the County Stone above it. The sections in different parts of Great Combe compare as follows:—

Great Combe, Crag Fell.

<i>North End.</i>	FEET.	<i>South End.</i>	FEET.
Shale.		} Shale with a concretionary cherty band	
Chert and sandstone - - - - -	5		14
Sandy limestone - - - - -	5	Limestone, black fine-grained	1½
Chert and shale - - - - -	10	Flaggy sandstone.	
Shale, about - - - - -	50		
MAIN LIMESTONE.			

The coal underlying the Main Limestone has been worked round this hill also.

The section below the Main Limestone runs on thus :—

<i>Crag Fell.</i>		FEET.
MAIN LIMESTONE	- - - - -	- 10 to 15
Sandstone	-	
Shale with coal	-	
Sandstone	-	
Shale	-	
	} - - - - -	- 80
UNDERSSET LIMESTONE	- - - - -	- 25
Sandstone, flags, and shale with two thin limestones	- - - - -	- 390
MIDDLE LIMESTONE	- - - - -	- 18
Sandstone	- - - - -	
Shale with thin limestone	- - - - -	
Sandstone	- - - - -	
Shale	- - - - -	
	} - - - - -	- 132
SIMONSTONE LIMESTONE	- - - - -	- 15
Sandstone with two thin limestones	- - - - -	- 75
HARDRAW SCAR LIMESTONE	- - - - -	- 15
Shale with some sandstone	- - - - -	- 70
GREAT SCAR LIMESTONE.		
		835

In Garsdale the Hardraw Scar or lowest limestone of Phillip's Yoredale series appears for a distance of about $2\frac{1}{2}$ miles. Its upper part crops out in the river near Low House and the whole bed in Blea Gill. Along this part of the dale it can be traced by swallow-holes only, but it comes into sight near Scar Top and Low Scar. It finally crosses the river again near Ingheads Bridge, absorbing the water in its fissures for a distance of about 200 yards. The rock is black and fine-grained, and about 20 feet thick; above it lie sandstone and flags with abundant and beautifully preserved annelid-tracks and ripple-marks.

The Simonstone Limestone also occurs as an inlier in Garsdale; it crosses the river 400 yards above Ingheads Bridge and runs down the dale for a distance of $3\frac{1}{2}$ miles, as far as Birkkrigg, where it again descends to the bed of the river. There usually occur two thin sandy limestones below it, as may be seen in Blea, Ray, Assey, and Skelton Gills on the south side of the dale, and in the bed of the river above Ingheads Bridge. In this part of the district, the underlying limestone sometimes equals the Simonstone itself in thickness.

The Middle Limestone runs through the whole length of Garsdale, and the thick sandstone below it forms a distinct feature in the sides of the dale. It is best seen in the gills in the upper part of the dale, in each of which it makes a conspicuous waterfall. Occasionally a thin limestone appears in the sandstone, as in Assey Gill, north of Ray Gill. The limestone itself is also split up rather irregularly by one or more sandstone-bands, and gains extreme hardness and a cherty texture, from the intimate mixture of finely-divided silica (probably as a fine sand) and carbonate of

W. 30° N.

Section from Barkin to Crag Fell, across the Dent Fault.

E. 30° S.

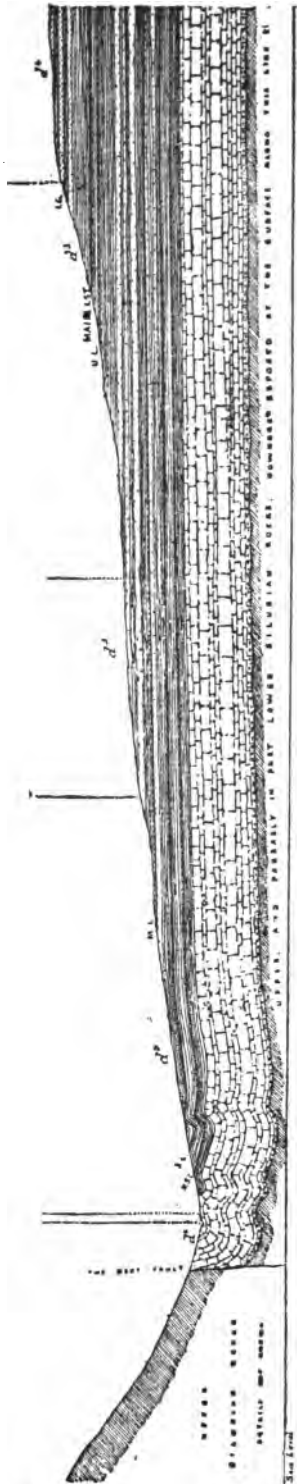
By A. STRAHAN.

Dent
and
Barkin
Beck.
Road.

Barkin
Calf Top.
1,800 feet.

Lofshaw
Brow.
Yorkshire Six-inch Map.
79 80

Crag
Fell.
2,250 feet.
The Crag.



Scale 3 inches to a mile.

d^f. Yoredale Rocks.

Main Lst. = the Main Limestone.

U. L. = the Underset Limestone.

M. L. = the Middle Limestone.

S. L. = the Simonstone Limestone.

H. S. L. = the Hardraw Scar Limestone.

d^a. Millstone Grit.

(1. G. The Ingleborough Grit.)

d^e. The Great Scar Limestone.

lime. One of the best exposures occurs in the railway-cutting above Scar Top, where the following section was taken :—

Railway-cutting above Scar Top.

		FEET.	
	Shale.		
	Sandstone - - - -	2	
	Shale - - - -	13	
MIDDLE LIMESTONE	{	Red sandy limestone - - - -	7
		Shale - - - -	8
		Limestone - - - -	10
		Sandstone - - - -	7
		Shale - - - -	$\frac{1}{2}$
		Sandy limestone - - - -	2
		Sandstone - - - -	1
		Limestone - - - -	6

On the opposite side of the dale is seen :—

MIDDLE LIMESTONE	{	Limestone, top not seen - - - -	10+
		Sandstone - - - -	6
		Limestone - - - -	5
		Sandstone - - - -	3+

The carbonised remains of *Calamites*, *Lepidodendron* and other plants occur in abundance in the débris from the Risehill Tunnel, which was driven chiefly through the sandstones associated with the Middle Limestone.

Above the Middle Limestone there lies a thick shale with a constant band of productal limestone, known from the appearance of the *Producti*, when cut across, as the Horseshoe, or Impure Productal Limestone, and believed to be the Five-Yard limestone of Teesdale and Alston Moor. It usually is divided into two parts by a band of shale, the lower bed being crowded with *Productus giganteus*, while the upper is generally stained red for a few inches by the percolation of ferruginous water from the shale above. Above the shale in which this limestone occurs another massive sandstone forms a second series of waterfalls. A generalised section in Garsdale run as follows :—

Garsdale.

		FEET.	
	Massive sandstone.		
	Shale - - - -	30 to 40	
FIVE-YARD LIMESTONE	{	Red-topped limestone - - - -	1 to 2 $\frac{1}{2}$
		Shale - - - -	1 to 2
		Productal limestone - - - -	2 to 3
		Shale, about - - - -	60
MIDDLE LIMESTONE.			

A second limestone from 1 to 2 feet thick, and believed to correspond to the Three-Yard Limestone of Teesdale, appears occasionally in Garsdale. It runs about 80 or 60 feet above the base of the sandstone last-mentioned, along the side of Rise Hill between Copplethwaite and Garsdale Hall Plantation, and again

on the north side of the dale above Dandra Garth. Some flaggy sandstones above this bed are largely worked in the Bridge End quarry, in levels which have been driven for two or three hundred yards into the hill. The thickness of strata between the Middle Limestone and the Underset amounts to about 350 feet. The Underset Limestone, and the beds above it, sweep round the upper part of Baugh Fell, Widdale, and Rise Hill so as to pass into the adjoining dales without a break. It enters this map for a short distance on the north side of Garsdale, where it has been worked for encrinital "marble." On the south side we follow it along the east and north sides of Rise Hill, but lose it completely on the west near the great fault. The limestone varies from twelve to sixteen feet in thickness, and always lies under a black calcareous shale, about seven feet thick.

It appears again with this calcareous shale near the Garsdale Coal-pits on the west side of Widdale Fell, as far as a small fault, south of which it disappears for some hundreds of yards, probably through having been removed partly or wholly by weathering. It reappears near Cowgill Beck Head, and runs thence round the Fell.

The Main Limestone also runs round the upper part of Rise Hill, at a distance of sixty to a hundred feet above the Underset. At the east end of the hill it forms a broad and nearly bare rocky plateau known as Snaizwold, and close by has been worked for encrinital "marble." On the north side of the hill a line of swallow-holes leads us along its outcrop up to an old quarry at the west end. About 200 feet above it there occurs a thin encrinital limestone about three feet thick but seen on the south and east sides of the hill only.

On the north-west side of Widdale Fell the Main Limestone makes a broad shelf, known as Cowgill Wold and Cotewold, most of which, and especially that part which is occupied by a small outlier of the shale that lies above the limestone, is over-spread by peat. The Cotewold limestone is separated from the main mass by a narrow breach, due evidently to the weakness caused by a small fault with a downthrow south of about twenty feet. Further to the north-east, along Mossdale Moor, some unusually large and numerous swallow-holes mark the outcrop of the Main Limestone. The thickness of the rock appears to be about 50-60 feet.

In the thick shale above it we occasionally see the thin limestone of Pike's Edge (p. 46). Near Widdale Little Tarn this band is black, gritty, and associated with chert, while the underlying sandstone resembles gannister, and contains rootlets and plant-remains.

Coal-seams in Garsdale.

A seam of coal between the Main and the Underset Limestone has been worked for a considerable distance on Widdale Fell, and in a few spots on Rise Hill. It is said to be 8½ inches thick and to

lie 18 yards below the Main Limestone at the Garsdale Coal-pit, where it has been won by means of levels driven in from the outcrop and by shafts sunk down to it through the limestone. It is still raised occasionally for burning lime. The old workings extend south as far as the Cross Pits Colliery, at the south end of the Fell. A second seam occurs about 50 feet above the Main Limestone and has been worked on Rise Hill and Baugh Fell, in both of which hills the coal below the Main Limestone appears to be absent or of insignificant thickness.

CHAPTER V.—CARBONIFEROUS ROCKS—*continued.*

DISTRICT 3. LITTONDALE.

By J. R. DAKYNS.

THIS district consists of Carboniferous Limestone and the Yoredale series, capped with outliers of Millstone Grit. The beds throughout are nearly horizontal, the average dip being 46' to the N.E. As the thickening of the beds amounts to an angle of 13° 5', it is possible that the entire amount of dip, 71 feet in a mile, is due to the original slope of deposition. This is the slope of the top of the Hardraw Scar Limestone. That of the Main Limestone is 50 feet per mile.

Above Hawkswick we have three principal limestones besides the Great Scar Limestone, viz., the Main, Middle, and Simonstone Limestones. The shales and sandstones which separate these are very irregular, continually coalescing and again splitting.

A band of shale is frequently seen a little way below the top of the Great Scar Limestone, the overlying rock being dark-coloured and highly fossiliferous in places. *Productus giganteus* is one of the most characteristic fossils of this bed. The sandstone overlying the Great Scar Limestone often has an intercalated bed of limestone in it. This is seen in Potts Beck and Newsholme-Gill.

A bed of sandstone occurs at the base of the Middle Limestone from Litton northwards. The sandstone above the Middle Limestone is divided at Litton by a bed of shale, above and below which occur two thin beds of impure limestone. These are seen in Crystal Beck, but cannot be traced; they probably correspond to the Five-Yards and Three-Yards Limestones. West of Littondale the series is more complex. Two or more bands of shale occur in the Great Scar Limestone, below that previously mentioned. These are seen on the south and west of Pennegent; the thin limestone intercalated in the lowest sandstone is seen on the north side of Fountain Fell, and in Foxup Beck. In the latter we have the following section:—

Foxup Beck.

	FEET.
Sandstone.	15
Shale, about	1
Limestone	5
Sandstone	5
Limestone	5
Sandstone, about	25

	FEET.
Shale - - - - -	} 50
Limestone, 1 foot	
Shale - - - - -	
Limestone, 1 foot	
Shale - - - - -	
Black limestone, the HARDRAW SCAR LIMESTONE	
Shale - - - - -	
White limestone	

On Fountain Fell this limestone is in one bed only two feet thick. On Scoska Moor an impure ferruginous limestone occurs in the shales below the Middle Limestone. This earthy limestone is also seen on the north side of Fountain Fell, where the following section occurs :—

Fountain Fell.

	FEET.
MIDDLE LIMESTONE.	
Shale - - - - -	} 50
Sandstone - - - - -	
Black limestone - - - - -	
Sandstone - - - - -	} 50
Black limestone - - - - -	
Shale - - - - -	
Sandstone - - - - -	
SIMONSTONE LIMESTONE - - - - -	

A somewhat similar series is seen east of Pennegent from Upper Healeden to the watershed between Littondale and Ribblesdale.

On Darnbrook* and Fountain Fells a remarkable section occurs. The upper part of the Yoredale Series there contains two well-marked and fairly thick limestones. At first sight it might naturally be thought that these were the Main and Underset Limestones, and so we thought when we were originally mapping the ground; but a further examination of the sections renders this doubtful. The strata between the two limestones consist of fissile calcareous cherts (shiver-beds), and these are so very much like the beds which in many places overlie the Main Limestone that one is led to suspect that the lower of our two beds is the Main Limestone, in which case the uppermost one would correspond to the Red Beds Limestone of Swaledale, where a similar cherty shivery series overlies the Main Limestone. It is also quite possible that the thick Main Limestone of Pennegent splits up southward so as to form the two bands of Darnbrook and Fountain Fell with their intermediate cherts.

On Fountain Fell there is a fair thickness of sandy shale between the top limestone and the pebbly Millstone Grit; but on Darnbrook there appears to be only a thin band of shale between the grit and the lower of the two limestones; so that it would seem that the pebbly grit descends across the beds so as quite to cut out the topmost limestone and all but rest on the lowermost. This is like to the behaviour of the lower pebbly Millstone Grit in other places.

* Darnbrough is the correct spelling of this name.

CHAPTER VI.—CARBONIFEROUS ROCKS—*continued.*DISTRICT 4. WHARFEDAILE WITH PARTS OF WALDEN,
BISHOPDALE, SEMMERDALE, SLEDDALE, SNAIZHOLME
WIDDALE, AND WENSLEYDALE.

By J. R. DAKYNS, with Notes by C. FOX-STRANGWAYS.

WHARFEDAILE.

IN Wharfedale the Great Scar Limestone presents its usual character of a massive scar-forming limestone, which weathering white gives that colour to the scars. These are formed by the limestone weathering out into terraces along lines of bedding; one bed of limestone being parted from the next by a thin seam of clay or of plate, a few inches thick. The limestone, being well jointed, weathers back by the successive fall of cubical masses; and thus, the escarpment retaining ever a vertical face, scars are formed. These terraces and scars, rising one above another in successive tiers, are the characteristic feature of the Dales; so much so that the Carboniferous Limestone is generally known as "the Scar Limestone."*

At Kettlewell the Great Scar Limestone is upwards of 775 feet thick; for that amount of solid limestone is seen without reaching the base. It is overlain by the following measures as given in a mine-section. From this it will be seen that there are about 253 feet of Yoredale Rocks. As we go west and north from Kettlewell, the upper part of the Great Scar Limestone splits up, so that the Yoredale beds become thicker, if by that term we mean all the beds seen in the valley of the Ure between the Millstone Grit and the thick undivided "Scar Limestone."

Section of Strata in the Providence Mine, near Kettlewell.†

		Ft. Lx.	
MILLSTONE	}	Grit, "girdles," and cover	30 0
		Plate and coal	2 0
		Grit	30 8
		Girdles and plate	24 0
		Grit	12 0
		Girdles and shale	22 8
		Coal	2 0
		Plate	24 0
		Main "Bearing Grit"	94 3

* This term is also applied to other beds than the Great-Scar Limestone. Thus on Alston Moor the Middle Limestone is called "the Scar Limestone."

† This section has been drawn to scale in Vertical Sections, Sheet. 28. The mine lies in Quarter-Sheet 97 S.E.

		Ft. In.
YOREDALE BEDS.	Plate -	36 0
	Limestone -	6 0
	Plate and lime-girdles -	15 0
	Limestone -	9 0
	Plate -	3 0
	Limestone -	8 0
	Plate and girdles -	18 9
	Limestone -	8 8
	Plate -	0 8
	Limestone -	6 0
	Plate -	4 6
	Limestone -	3 8
	Plate -	0 8
	Limestone -	36 0
	Limestone -	60 0
	Plate -	18 0
Limestone -	48 0	
Dirt Pot Grit -	9 0	
Plate -	4 0	
Blue grit and plate -	10 6	
GREAT SCAR LIMESTONE.	Limestone -	5 6
	Plate -	3 0
	Limestone -	over 775 0
		1,330 6

A section plotted across Old Cote Moor, W.N.W. of Kettlewell, gives the following section of beds as seen on the ground :—

Old Cote Moor, Kettlewell.

	FEET.
MAIN LIMESTONE -	about 30
Shale -	from 90 to 120, say 105
Sandstone -	60 to 40, say 50
Shale -	40 to 35, say 37
MIDDLE LIMESTONE -	50
Shale -	50 to 60, say 55
SIMONSTONE LIMESTONE -	50
Sandstone -	20
Shale -	10
GREAT SCAR LIMESTONE -	750 seen.

The sandstone below the Simonstone passes into shale as we follow the beds up Wharfedale, or becomes split up with shale-bands; and the sandstone above the Middle Limestone behaves in a similar manner.

In Bowther Gill we have the following section :—

Bowther Gill.

	FEET.
MIDDLE LIMESTONE -	not less than 60
Sandstone -
Gap, strata not seen -
Limestone (probably) -
Gap -
Sandstone -
Gap -
SIMONSTONE LIMESTONE -	20

	FEET.
Sandstone, thick	}
Shale, thick	}
Limestone, 3 feet	}
Sandstone, 10 or 12 feet	}
Limestone, 4 or 5 feet	}
Plate	}
Calcareous sandstone with rootlets, 14 inches	}
Shale	}
Plate	}
Limestone with <i>Productus giganteus</i> ; top of the GREAT SCAR LIMESTONE.	55
Plate.	
Limestone.	
Plate.	
Limestone, thick.	

The next gill, Mill Beck, gives the following section :—

Section in Mill Beck.

	FEET.
SIMONSTONE LIMESTONE	over 24
Sandstone	17
Limestone	3 to 4
Sandstone	4 to 5
Limestone	6
Sandstone	30
Shale	not less than 5
Limestone with corals and <i>Productus giganteus</i>	22
Shale and gap	10
Limestone	20
Shale	4 or 5
Thick Limestone.	

The Simonstone and Middle Limestones are continuous all along Wharfedale above Kettlewell.

The Underset Limestone sets in somewhere on the obscure hill-side opposite Buckden; we first see it in force forming a crag near Low Comb opposite Kirk Gill. It again shows itself on the path leading over the fell from Raysgill in Wharfedale into Littondale near Horse Head,* but cannot be traced continuously. The Main Limestone runs all round the hill-side below the top of Old Cote Moor, which is formed of Millstone Grit. The Main Limestone also forms an outlier on Horse Head Moor, Horse Head itself being a small outlier of Millstone Grit.

A plotted section across the Haws gives the following thicknesses :—

The Haws.

	FEET.
MAIN LIMESTONE, upwards of	50
Sandstone and shale	60
UNDERSSET LIMESTONE	60
Measures	225 to 250
MIDDLE LIMESTONE	65
Measures	50
SIMONSTONE LIMESTONE	20
Measures	50
Limestone with <i>Productus giganteus</i> .	

* This should be Haws Head.

Another section plotted across Little Fell gives the following:—

Little Fell.

	FEET.
MAIN LIMESTONE	60
Measures, mostly sandstone	130
UNDERSSET LIMESTONE	65
Sandstone	} 180
Ferruginous shale with a thin limestone near the bottom*	
MIDDLE LIMESTONE	45
Sandstone with thin limestones on shale	35
SIMONSTONE LIMESTONE	60
Sandstone	} 65
Limestone	
Sandstone	
Limestone	
Sandstone	
GREAT SCAR LIMESTONE; with <i>Productus giganteus</i>	} about 100
Plate, thin	
Limestone, coralline	
Shale, very thin	
Limestone	
Shale, very thin	
Limestone, thick	-

Throughout Wharfedale and Littondale the top of the Great Scar Limestone is marked by a productal band containing especially *P. giganteus*. The thin subdivisions given near the top of this limestone, in the above section, become important northward, the upper limestone with *P. giganteus* becoming the Hardraw Scar Limestone; but in this part of the country these subdivisions cannot well be separated from the main mass of the Great Scar Limestone.

Westward from Little Fell and the line of the above section, the beds forming the upper part of the Great Scar Limestone are obscured by the Drift which about Greenfield covers the watershed between the Wharfe and the Ribble, but the Yoredale beds can be traced on tolerably well, as the Simonstone and Middle Limestones are everywhere important beds. The Middle Limestone is generally covered by a considerable thickness of ferruginous shales, containing a thin limestone marked * in the section given above. This is the Impure Productal Limestone of Prof. Phillips.

The fell-side below Greenfield Knotts shows a similar sequence of beds to that given above. The Undersset Limestone is present, and an outlier of Main Limestone forms Greenfield Knotts.

The country between Greenfield and Outershaw Becks consists of an outlier of the lower Yoredale Rocks, the top of the hill, called Cocklee Fell, being formed of the sandstone-series above the Middle Limestone. The series from this point towards Beckermonds is as follows:—

Between Cocklee Fell and Beckermonds.

	FEET.
Sandstone-series	100
MIDDLE LIMESTONE	50
Sandstone	25

* The Impure Productal or Five-Yards Limestone.

	FEET.
Shale	} 90
Sandstone	
Plate	
SIMONSTONE LIMESTONE	} 80
Flagstone	
Gap, strata not seen	} 120
Limestone, 8 inches, rusty and adhering to	
Sandstone	
Shale, 8 feet	
Limestone, 3 feet	
Sandstone	} 60
Plate	
Limestone, productal (the HARDRAW SCAR LIMESTONE)	
Shale, thin	} 60
Limestone	
Plate	
Limestone	
Shale, 3 feet	
GREAT SCAR LIMESTONE	

Sections in Outershaw give the following series of beds :—

Outershaw.

	FEET.
MAIN LIMESTONE	100
Shale	} 80 to 90
Sandstone	
Shale	
Grit	
Plate and black shale	
Chert	} 30
Limestone and plate	
UNDERSSET LIMESTONE	} 300
Sandstone and shale, variable	
Limestone	
Sandstone	
Shale	} 50 to 80
Sandstone	
MIDDLE LIMESTONE	} 30
Shale and coal	
Sandstone	} 90 to 100
Shale	
Limestone	} 30 to 25
Shale	
Sandstone	} 180
Limestone, 3 feet	
Sandstone	
Shale	
Calcareous sandstone	} 60
Shale	
Limestone, productal and coralline (the HARDRAW SCAR LIMESTONE)	
Shale	
Limestone	
Shale	
GREAT SCAR LIMESTONE.	

As we follow the beds south-eastward down the north and east side of Wharfedale from Outershaw to Kettlewell, we find the following general series:—

- The **MAIN LIMESTONE**; everywhere present, thinning south-eastwards.
 Sandstone, passing into shale.
UNDERSET LIMESTONE; continuous as far as Cam Head, north of Kettlewell, where it passes into chert.
 Shale; thinning out south-eastwards.
 Sandstone; continuous to Cam Head, where it thins out.
 Shale.
MIDDLE LIMESTONE.
 Sandstone; in force as far as Buckden Beck.
 Shale.
 Sandstones and shales with thin limestones; becoming feeble to the south-east.
SIMONSTONE LIMESTONE.
 Shales and sandstone.
HARDRAW SCAR LIMESTONE; coalescing with the Great Scar Limestone south-eastwards.
 Shale thinning out south-eastwards.
GREAT SCAR LIMESTONE.

We will now give the sections of the chief gills on the left-hand side of the Wharfe. The first big gill below Beckermonds is Deepdale,* which gives the following section:—

Section in Deepdale, Wharfedale.

	FEET.
MILLSTONE GRIT	
CARBONIFEROUS LIMESTONE SERIES:—	
Plate	
MAIN OR COVERHEAD LIMESTONE	}
Limestone.	
Plate.	50
Limestone	3
Shale	
Sandstone	
Plate	50
UNDERSET LIMESTONE	50
Sandstone	}
Shale	
Sandstone	
Shale	
Limestone, thin	
Sandstone, upwards of	50
Plate	}
Limestone, 2 to 4 feet	
Shale	70 to 80
MIDDLE LIMESTONE	40
Shale, 4 feet, with coal occasionally	}
Sandstone and shale	
Sandstone, 50 feet	
Shale and sandstone	
Sandstone, 7½ feet	110
Shale	
SIMONSTONE LIMESTONE	25

* A dale of the same name lies on the south side of Dent.

	FEET.
Sandstone	} 80
Limestone	
Shale	
HARDRAW SCAR LIMESTONE	40
Calcareous sandstone	} 40
Shale	
GREAT SCAR LIMESTONE, seen to	275

Near Yockenthwaite the section of the lower Yoredale Rocks on the north side of the Wharfe is as follows :—

Section north of the Wharfe, near Yockenthwaite.

	FEET.
MIDDLE LIMESTONE	50
Shale and coal	} 70
Sandstone, thick	
Shale	
Limestone	
Shale	} 40
Sandstone, thick	
SIMONSTONE LIMESTONE	} 70 or 80
Sandstone, thick	
Shale	
Sandstone, 6 inches	} 25 to 30
Shale, 2 feet	
Sandstone, thick	
HARDRAW SCAR LIMESTONE, coralline	} 40
Shale	
Limestone	
Sandstone	
Plate	} 400
GREAT SCAR LIMESTONE :—	
Limestone	
Shale, 2 inches	} 400
Limestone, seen to	

West of Cray we get the following section :—

Section in Crook Gill.

	FEET.
MIDDLE LIMESTONE	50
Shale	} 110
Sandstone	
Shale	
Thin impure and flaggy limestone	
Shale	} 25
Plate	
SIMONSTONE LIMESTONE	} 75
Sandstone, 15 feet	
Shale, 10 feet	
Limestone, 1 foot	
Sandstone	
Plate	} 50
Limestone	
Plate, 3 feet	
HARDRAW SCAR LIMESTONE, with <i>Productus giganteus</i> and corals	} 50
Plate, thin	
Limestone	
Sandstone	
Limestone	} 50
Plate, thin	

	FEET.
GREAT SCAR LIMESTONE:—	
Limestone	25
Shale	1½
Limestone, seen to	350

Section in Buckden Beck.

MILLSTONE GRIT (p. 77)	470
CARBONIFEROUS LIMESTONE SERIES:—	
MAIN LIMESTONE	100
Shale	40
UNDERSÉT LIMESTONE	100
Shale	40
Sandstone	40
Shale	20
MIDDLE LIMESTONE	110
Sandstone and shale	30
SIMONSTONE LIMESTONE	40
Sandstone and shale	60
HARDRAW SCAR LIMESTONE (<i>Productus hemisphericus</i> plentiful near Buckden)	30
Thin plate	-
GREAT SCAR LIMESTONE, seen to	500

WALDEN.

A very small portion of Walden comes into this Quarter-Sheet. We have there the two upper limestones, but rather thinner than as given above, viz., the Main Limestone, 80 feet, and the Under-set Limestone, 75 feet thick. Over the Yoredale Beds lies the Millstone Grit, as shown in the section of Buckden Moor.

BISHOPDALE.

The upper portion of Bishopdale comes into this map; and here we have the following general section of the Yoredale Rocks:—

	FEET.
MAIN LIMESTONE	100
Shale and sandstone	50
UNDERSÉT LIMESTONE	60
Shale	} 245
Sandstone	
Shale	} 30 to 50
MIDDLE LIMESTONE	
Sandstone and shale	75 to 130
SIMONSTONE LIMESTONE	20 to 30
Sandstone	75 to 80
HARDRAW SCAR LIMESTONE	35 to 50
Plate, thin.	
GREAT SCAR LIMESTONE.	

The best section is in Foss Gill; it is given below:—

Section of Foss Gill.

	FEET.
Shales, ferruginous	-
Limestone (Phillips's Impure Productal Limestone)	2
Plate	-
MIDDLE LIMESTONE, at the first or highest foss	30

	FEET.	
Sandstone, 5 feet	} 130	
Shale		
Limestone, 2 feet		
Shale, 1½ feet		
Limestone, 1 foot		
Shale, 1 foot		
Sandstone, over 4½ feet		
Gap, strata not seen		
Limestone, 6 feet		
Plate, 1 foot		
Sandstone, thick		
SIMONSTONE LIMESTONE, at the second foss		20
Sandstone		50
Shale		30
HARDRAW SCAR LIMESTONE, at the third foss		35
Plate		
Limestone	3	
Shale	1½	
Plate, more than	3	
Shale		
LIMESTONE		
Shale, at the fourth foss	5	
LIMESTONE		

On the east side of the dale we have the following sections:—

East side of Bishopdale.

	FEET.	
MIDDLE LIMESTONE: its base at the limekiln above West		
Howgill House	50	
Sandstone	} Section in gill above Holme Field - 100 +	
Sandstone and shale		
Gap		
Limestone resting on sandstone		
Gap		
Limestone		
Shale, 3 feet		
Sandstone, 3 feet		} Section in wood above High West Field - 100 +
Limestone, 1 foot		
Sandstone		
Gap		
LIMESTONE, near the bottom of the wood.		

And again a little farther north, we have the following parallel sections, viz:—

<i>In Myres Garth Gill (in the Upper Wood).</i>	<i>In Scale Gill.</i>	FEET.
Ferruginous shales.	Ferruginous shales.	
MIDDLE LIMESTONE	A little limestone and thin plate (just above the wood).	About 50
Limestone }	MIDDLE LIMESTONE.	} About 75
Sandstone }	Shale.	
Shale, thick	Sandy limestone.	
Limestone, 2½ feet	Sandstone.	
Slate, 1 foot	Sandy limestone.	
Sandstone, 4 feet	Plate.	
Plate	Shale, thick.	
SIMONSTONE LIMESTONE (at the bottom of the wood).	Limestone.	
	Limestone, sandy.	
	Plate.	
	Limestone, impure.	About 80
	SIMONSTONE LIMESTONE.	

At Woods Plantation, above New House, we have the section continued thus:—

	FEET.
SIMONSTONE LIMESTONE (at the top of the wood).	
Sandstone, 2 feet	-
Shale, 1 foot	-
Sandstone	-
Gap	-
Limestone, sandy	-
Limestone	-
Sandstone	-
Limestone, sandy and ferruginous	-
Sandstone	-
Gap	-
Sandstone	-
Shale	-
HARDRAW SCAR LIMESTONE	-
Shale	-
LIMESTONE	-
Shale	-
LIMESTONE	-
Shale	-
LIMESTONE	-

On the west side of Bishopdale the uppermost Yoredale beds are different from those on the east side in the following important respects. On the east side along Bishopdale Edge the Main Limestone is immediately overlain by Millstone Grit; but on the west side we have above the ordinary Main Limestone of Kidstones Fell and Stake Moss upwards of 50 feet of cherty beds on Thoraby Common. The series on the north end of the Stake is as follows:—

	FEET.
Cherty beds, upwards of	50
MAIN LIMESTONE, white	100
Sandstone, at Stake Edge	50
UNDERSET LIMESTONE	60

We can complete the list of the beds between Bishopdale and Semmerdale with a section from Addlebrough, which is formed by an outlier of the Underset Limestone, to Cubeck.

Section from Addlebrough to Cubeck.

	FEET.
UNDERSET LIMESTONE, of Addlebrough, whole thickness not seen	50
Sandstone	10
Sandstone and shale	260
MIDDLE LIMESTONE	75
Shale	15
Sandstone	40
Shale	20
Sandstone	25
Shale	50
SIMONSTONE LIMESTONE	50
Sandstone	20
Shale	20
Sandstone	10
HARDRAW SCAR LIMESTONE	80

SEMNERDALE.

We will introduce the description of the beds in Semnerdale by a section plotted from the Ordnance Station 1659 on Stake Fell to Semner Water.

Section from Stake Fell to Semner Water.

	FEET.
MAIN LIMESTONE	
Sandstone	15
Shale	40
UNDERSSET LIMESTONE	55
Sandstone	75
Shale	5
Sandstone	100
Shale	15
Sandstone	30
Shale	30
Sandstone	20
Shale	20
MIDDLE LIMESTONE	70
Sandstone and shale	75
SIMONSTONE LIMESTONE	55
Sandstone	} 90
Shale	
Limestone	
Sandstone	
Shale	
HARDRAW SCAR LIMESTONE	50
Sandstone and shale	40
GREAT SCAR LIMESTONE.	

With the above we may compare a section on the west side of the dale from Green Scar to Semner Water, which gives:—

From Green Scar to Semner Water.

	FEET.
UNDERSSET LIMESTONE, of Green Scar Crag, over	20
Sandstone	45
Sandstone and shale series	130
Shale with thin "Impure Productal Limestone," near the base	150
MIDDLE LIMESTONE	50
Measures	110
SIMONSTONE LIMESTONE	40
Measures	80
HARDRAW SCAR LIMESTONE	35
Sandstone	20
Limestone	

In Semnerdale, where we get clear sections, we see that the Carboniferous Limestone is still further splitting up. The Hardraw Scar Limestone is now always definitely parted from the beds below, and the lower beds exhibit alternations; thus in the gill on which Raydale House stands, and on Ballinside Moor we have:—

Raydale and Ballinside.

	FEET.
MIDDLE LIMESTONE	
Sandstone	} 130
Thin brown limestone with <i>Canda galli</i>	
Sandstone	
Ferruginous shale	

	FEET.
SIMONSTONE LIMESTONE -	30
Sandstone	12
Shale	6
Sandstone	6
Limestone	2
Sandstone	50
HARDRAW SCAR LIMESTONE, about	50
Sandstone	} 18
Shale	
Limestone	50
Shale	2
Limestone*	50
Sandstone*	} about 12
Shale*	
Thick Limestone.	

The beds marked thus * are seen at the back of Raydale House. The sandstone appears also at the foot of Park Scar and again at the foss in Startling Wood, where the section is :—

Limestone.
Sandstone, 6 feet.
Shale, 8 feet.
Coralline limestone.

We get the following sections in Thornrake Gill at the head of Cragdale :—

Cragdale.

	FEET.
MILLSTONE GRIT.	
CARBONIFEROUS LIMESTONE SERIES :—	
MAIN LIMESTONE, about	90
Sandstone	} 65
Gap, strata not seen -	
UNDERSSET LIMESTONE, forming Green Scar	70
Shale	} 140
Sandstone and shale	
Sandstone	
Limestone, 6 feet	
Plate	} 40
Limestone, 1 foot, fine-grained and smooth	
Shale	
Limestone, 1 foot, with fossils	} 50
Shale	
Limestone, thin	} 50
Shale, ferruginous, about	
MIDDLE LIMESTONE	50
Shale	1½
"Seat-stone," with <i>Stigmaria</i>	1½
Sandstone.	

It is as well to remark that throughout the Wensleydale basin the Middle Limestone is distinguished by having a coal near its base.

At the head of Raydale we have measures as below :—

Raydale Head.

	FEET.
MAIN LIMESTONE	90
Gap, strata not seen	80
UNDERSSET LIMESTONE	50

	FEET.
Sandstone	} 270
Shale	
Limestone	
Sandstone	
Calcareous sandstone or limestone	
Sandstone	
Calcareous sandstone	
Shale	
FIVE-YARDS OF "IMPURE PRODUCTAL" LIMESTONE	
Ferruginous shale	
MIDDLE LIMESTONE	} 30

The beds, though not well seen in Bardale owing to the great amount of Drift there, are found in their normal form on both sides of the dale.

A horizontal section from Green Side across Bardale Head and Raydale to Stallion Busk Pasture gives the following thicknesses of beds below the Underset Limestone, showing the variations from west to east :—

Bardale and Raydale.

	FEET.
Sandstones and shales with two thin limestones	280 to 220
MIDDLE LIMESTONE	50 to 50
Sandstone, about 30	} 90 to 100
Shale, about 70	
SIMONSTONE LIMESTONE	50 to 70
Measures	80 to 40
HARDRAW SCAR LIMESTONE	45 to 50

The best section in Bardale is in Ash Gill above Marsett. At the top of the hill on Carlows we have the Main Limestone; below it beds as follows :—

Bardale.

	FEET.
Sandstone and shale	} 260
UNDERSSET LIMESTONE	
Sandstone	
Shale and sandstone	
A small limestone	
Ferruginous shale	
FIVE-YARDS LIMESTONE, 1 foot, with corals	
Shale	
MIDDLE LIMESTONE	
Shale and coal, 3 feet	
Sandstone	} 100
Shale	
A thin limestone	
Sandstone	
Shale	} 55
SIMONSTONE LIMESTONE, at High Ashgill Scar	
Sandstone	30
HARDRAW SCAR LIMESTONE, at Low Ashgill Scar	60
Sandstone	50
Limestone in the main beck	
Thin shale	
Limestone	

On Wetherfell we have between the Main Limestone and the Millstone Grit, which forms a small outlier on Drumaldrace, a set of cherty beds similar to those on the Stake. One of the calcareous seams in this series is crowded with fossils. This cherty series is the equivalent of the cherty beds of Swaledale mentioned above.

SLEDDALE, SNAIZHOLME, AND WIDDALE.

The sequence of beds in Sleddale will be best shown by giving the results of a section drawn from the summit of Wetherfell across Ten End into Snaizholme:—

<i>Sleddale.</i>					FEET.
MAIN LIMESTONE	-	-	-	-	80
Sandstone and shale	-	-	-	-	50 or 60
UNDERSSET LIMESTONE	-	-	-	-	70 to 80
Sandstone and shales	-	-	-	-	270 to 300
MIDDLE LIMESTONE	-	-	-	-	70 or 80
Sandstone and shales	-	-	-	-	130 or 120
SIMONSTONE LIMESTONE	-	-	-	-	60 or 70
Sandstone and shale	-	-	-	-	100 or 90
HARDRAW SCAR LIMESTONE	-	-	-	-	80

Of the base of the outlier of Underset Limestone forming Snaizholme Wold, Prof. Hughes notes:—"Flaggy limestone with *Fenestella*, resting on sandstone with a concretionary band, about 2 inches thick, on top, which sticks out like a cap on weathered blocks. The limestone is irregularly horizontal all over this hill, but is bent rather sharply over at the north and more so at the south end, where perhaps there are some cracks; but of this there is no direct evidence."

There are very good sections in Duerley Beck and in Little Ing Gill at the head of Sleddale. We have between Dodd Fell and Hawes the following measures:—

Section between Dodd Fell and Hawes.

					FEET.
MILLSTONE GRIT (p. 76).					
CARBONIFEROUS LIMESTONE SERIES:—					
Shale	-	-	-	-	60
Sandstone, 3 to 20 feet	-	-	-	-	
Shale	-	-	-	-	90
MAIN LIMESTONE	-	-	-	-	
Sandstone	-	-	-	-	80
Shale	-	-	-	-	
UNDERSSET LIMESTONE	-	-	-	-	30
Sandstone (flags)	-	-	-	-	about 100
Shale	-	-	-	-	
"THREE-YARDS LIMESTONE" passing down into	-	-	-	-	about 250
Sandstone, at the waterfall south of Dodd House	-	-	-	-	
Shale	-	-	-	-	
Sandstone with subordinate shale-bands	-	-	-	-	
Shale	-	-	-	-	about 250
"FIVE-YARDS LIMESTONE," 2 feet, in shale full of fossils	-	-	-	-	
Shale	-	-	-	-	

	FEET.
MIDDLE LIMESTONE. { Limestone, 5 feet	50
{ Shale, 3 feet	
{ Limestone, 42 feet	
Sandstone with coal, at the lime-kiln east of Dodd House	about 100
Limestone, 3 feet -	
Sandstone, on the horizon of the Gayle Flags	
Shale	
Sandstone -	25 or 30
SIMONSTONE LIMESTONE	
Sandstone	50 to 80
HARDRAW SCAR LIMESTONE, above Duerley Bottom (in two beds about Gayle)	
Sandstone	50 to 75
Shale with nodules of ironstone	
Limestone, at Gayle	
Shale	
Limestone, at Hawes.	about 9
Sandstone.	
Limestone.	

Sections in Snaizholme are generally poor, but in Rigg's Gill and Green Sike we get the following:—

Snaizholme.

	FEET.
MIDDLE LIMESTONE	30 to 50
Coal	
Sandstone -	about 80
Shale	
Limestone, 1 foot	
Sandstone, 15 feet	
Shale	
Limestone	
Sandstone	
Shale	30
SIMONSTONE LIMESTONE	

The best sections are in the "grains" at Grove (or Groove) Head, particularly in Long Sike and North Scar Gill. There we have:—

Snaizholme.

	FEET.
MAIN LIMESTONE, forming High Wold	about 100
Sandstone	
Shale	
UNDERSSET LIMESTONE, forming Middle and Little Wolds	25 to 50
Shale	
Limestone, sandy and containing univalves	about 270
Sandstone	
Shale	
Limestone, thin and adhering to Sandstone	
"FIVE-YARDS LIMESTONE," 3 feet, impure and earthy	
Shale, 10 to 15 feet	25 to 30
MIDDLE LIMESTONE	

	FEET.
Sandstone, 2 feet -	}
Coal, 6 inches -	
Shale -	
Sandstone, forming North Scar -	}
Shale -	
Limestone, 2 feet -	}
Sandstone -	
Shale -	
SIMONSTONE LIMESTONE -	10 to 30
Sandstone -	}
Limestone -	
Sandstone -	
Shale -	
HARDRAW SCAR LIMESTONE.	about 50

Prof. Hughes observed *Productus latissimus* at Grove Head in a black limestone, which is either the Underset Limestone or a bed just below it. The base of the Underset in Jam Sike on the west side of this fell he described as "shaly flaggy limestone with *Fenestella*, *Pecten*, &c.," and on Little Wold as calcareous sandstone and shale with similar fossils.

Sections plotted across Dodd Fell and Snaizholme Fell give the following thicknesses of measures:—

Snaizholme and Dodd Fells.

	FEET.
MAIN LIMESTONE -	100
Sandstone -	30 or 40
Shale -	30 to 40
UNDERSSET LIMESTONE -	40 or 50
Sandstone, 70 feet	}
Shale, 100 feet	
Sandstone, 90 feet	
Shale, 30 feet	
Sandstone, 50 feet	
MIDDLE LIMESTONE -	40 or 45
Measures -	100
SIMONSTONE LIMESTONE -	30
Measures -	70
HARDRAW SCAR LIMESTONE	50

We get another fair section in Broad Foot Gill, which starts from a spring at the bottom of the Underset Limestone capping Snaizholme Fell. It is as follows:—

Snaizholme, west side.

	FEET.
UNDERSSET LIMESTONE, of Snaizholme Fell	}
Sandstone -	
Shale -	
Sandstone, thin -	
Shale -	
Sandstone, 20 or 30 feet	}
Shale -	
Sandstone -	40
Sandstone -	50
Sandstone and shale -	60
Shale -	40
Limestone -	21

	FEET.
Shale	50
MIDDLE LIMESTONE	30
Shale	20
Sandstone	30
Measures	55
SIMONSTONE LIMESTONE	30
Measures	70

In Wensleydale itself there are good sections in the gill that runs from Wetherfell to Hawes, and in Ray Gill east of Burtersett. In the first locality we have on the fell above the gill:—

Wetherfell, near Hawes.

	FEET.
Cherty beds with fossils, forming Wetherfell Peat Ground	
MAIN LIMESTONE, forming Cavy Clints, about	100
Sandstone and shale	80
UNDERBÆT LIMESTONE, forming Yorburgh, at the base of which springs the water of the gill	60
Sandstone with subordinate shale	
Shale	
Limestone, thin (probably the "Three-Yards Limestone") }	120
Sandstone	
Shale	
Sandstone	
Shale	100
Shale	25
Limestone with large <i>Producti</i> (probably the "Five-Yards Limestone").	
Shale, about	10
MIDDLE LIMESTONE	50
Sandstone with coal (1 to 3 inches thick); its base at the waterfall	15 or 20
Shale	
Sandstone, at the waterfall	
Shale	
Sandstone, flaggy, at the waterfall	25
Shale, over	50
SIMONSTONE LIMESTONE, about	25
Sandstone, over	50
HARDRAW SCAR LIMESTONE, forming two features, about	75
Sandstone	
Shale	
Gayle Limestone	about 50

In Ray Gill the beds above the Middle Limestone are much obscured by Drift, but at the foss near Four Lane Ends we have:—

Ray Gill.

	FEET.
MIDDLE LIMESTONE, about	50
Coal 3 inches, seen a little further east.	
Shale	
Sandstone, at Horton Gill Force	
Shale	
Sandstone, at Horton Gill Brig	25
Shale	between 25 and 50
SIMONSTONE LIMESTONE	23
Sandstone	over 20
Shale	6 to 8

	FEET.
Limestone	4
Shale	2
Sandstone	8
Limestone	1
Shale; thin	8
Sandstone	6
Shale	53
HARDRAW SCAR LIMESTONE	
Sandstone	

The section below Widdale Fell composed from the several small streams on the east side is as follows:—

Section below Widdale Fell.

(Thicknesses estimated from plotted section.)

	FEET.
MILLSTONE GRIT (p. 76).	
CARBONIFEROUS LIMESTONE SERIES:—	
Sandy shales and shales with cherty bands	80
MAIN LIMESTONE (encrinital)	75
Measures with a coal-seam and cherts in the lower part	70
UNDERSSET LIMESTONE	20
Flaggy sandstones and shales (thin limestone near the top and close to the bottom)	300
MIDDLE LIMESTONE	70
Measures with two thin limestones,* and a coal seam 8 ins. thick, but frequently too close to the Middle Limestone to be worked	110
SIMONSTONE LIMESTONE	25
Measures with two thin limestones	80
HARDRAW SCAR LIMESTONE	70
Measures, mostly shale	120
Limestone.	

Section at the North End of Widdale.

	FEET.
MILLSTONE GRIT (coarse grit).	
CARBONIFEROUS LIMESTONE SERIES:—	
Shales, not less than	60
MAIN LIMESTONE	80
Sandstone and shale	20 to 35
Coal, 4 to 8 inches.	
Sandstone and shale	60
UNDERSSET LIMESTONE (the upper part dark and cherty)	20
Sandstone and shale	100
Yellow limestone	5
Sandstone, flags, and shales	70
Crinoidal limestone-band	1 to ½
Sandstone and shale	50
Limestone with <i>Productus</i>	9
Strong flagstones and shales with fossils (becoming all shale and much thinner to the east)	50 to 100
MIDDLE LIMESTONE {	
Limestone	6
Shale with fossils	3
Limestone	15
Thin parting	2
Spotted limestone	8

* Perhaps these correspond to the "Single-post" and "Cockle-shell" Limestones of Teesdale.—J. R. D.

	FEET.
Sandstone and shale, 12 feet	} about 130
Irregular dark impure limestone, 1½ feet	
Sandstone and shale, 5 feet	
Coal, 6 inches to 1 foot	
Sandstone and shale, 35 feet	
Limestone, 1½ feet	
Sandstone and shale	} 20 to 30
SIMONSTONE LIMESTONE	
Shales and sandstone with two thin limestones	40 to 60
HARDRAW SCAR LIMESTONE, sometimes in two beds	50
Sandstone	} 80 to 100
Shale	
Limestone.	

CHAPTER VII.—CARBONIFEROUS ROCKS—*continued.*

BY J. R. DAKYNS, with Notes by C. FOX-STRANGWAYS
and W. GUNN.

MILLSTONE GRIT.

THE shales which lie between the Main Limestone and the Millstone Grit are only obscurely seen on Ingleborough. They are visible on Simon Fell in several swallow-holes.

The grit, which forms the top of Ingleborough, is coarse and pebbly. It dips to the E.N.E. and there are large slipped masses of it on the north and east sides of the fell, which obscure the beds below. This grit is without any doubt the same bed as one which years ago was mapped in Wharfedale as Millstone Grit and so coloured on the published maps, because it was believed to be the equivalent of part of the Kinderscout Grit. At the same time there is no doubt that in other parts of the country a different horizon has been taken as the base of the Millstone Grit. For the Ingleborough Grit, as Phillips pointed out, is the same bed as that on Pennegent *below the coal*; and this coal is probably the same seam as one which elsewhere has been taken as the base of the Millstone Grit.

The best sections of the beds above the Main Limestone occur on Whernside and on Pennegent. With the assistance of Mr. John Leyland, of Kettlewell, the beds on Pennegent above the Main Limestone were measured by means of a tape and an aneroid, as checks upon each other. The following results, which have been published in a diagram on Sheet 28 of Vertical Sections of the Geological Survey, were then obtained.

Section of the Millstone Grit and Yoredale Beds down to the Main Limestone on Pennegent.

Summit 2273·5 feet above sea-level.

	FEET.
No section for - - - - -	56
Shale - - - - -	-
Grit - - - - -	18
Shale - - - - -	33
Grit - - - - -	44
Shale - - - - -	10
Grit - - - - -	12
Shale - - - - -	12
Coal-smut - - - - -	-
Grit - - - - -	18
Coal - - - - -	-
A Grit, 75 to 81, say - - - - -	78
Shale, 25 to 36, say - - - - -	30
B Grit and Sandstone } 50 to 66, say - - - - -	58
Shale - - - - -	9
Main Limestone.	-

Our measurements were made up the south-eastern face of the fell. In places a shale-band comes in between the grit and sandstone in the 58-feet bed. B is probably the representative of the Ten-Fathom Grit of Swaledale. A is the Ingleborough Grit.

On the east side of the hill the base of A is ninety feet above the Main Limestone; and at the south end it is eighty feet above it; but along the western face of the fell it runs rapidly down northward, till it is not more than ten or fifteen feet above the limestone. We have then on Pennegent about 378 feet of measures, consisting of sandstones and shale with two coal-seams, above the Main Limestone. The whole of this will be referred to the Millstone Grit, if we take as before the top of the limestone as the base of the Millstone Grit; but, as has been done in other parts of the country, we class with the Yoredale Series the beds possibly equivalent to the Ten-Fathom Grit, and therefore we take the base of the Millstone Grit at the base of the Ingleborough Grit. On Fountain Fell only 176 feet of measures occur above the limestone, and east of Littondale not more than 50 or 60 feet, the whole of which is coarse grit.

A boring near Fountain Fell Tarn gave the following section:—

	THICKNESS.		DEPTH FROM SURFACE.	
	Ft.	In.	Ft.	In.
No. 25. Grit	15	0	15	0
„ 24. Shale	3	0	18	0
„ 23. Grit	12	0	30	0
„ 22. Grit and shale	12	0	42	0
„ 21. Shale	18	0	60	0
„ 20. Grit	2	0	62	0
„ 19. Plate	6	0	68	0
„ 18. Conglomerate	6	0	74	0
„ 17. Plate	1	0	75	0
„ 16. Coal	—	4	75	4
„ 15. Grit	9	0	84	4
„ 14. Shale	14	0	98	4
„ 13. Coal	—	4	98	8
„ 12. Shale	6	0	104	8
„ 11. Coal	—	3	104	11
„ 10. Shale	2	0	106	11
„ 9. Coal	—	4	107	3
„ 8. Shale	16	0	123	3
„ 7. Conglomerate	5	0	128	3
„ 6. Grit	8	0	136	3
„ 5. Shale	9	0	145	3
„ 4. Conglomerate	4	0	149	3
„ 3. Grit	8	0	157	3
„ 2. Shale	3	0	160	3
„ 1. Coal	2	4½	162	7½

On the escarpment eastward a quarry gives the thickness of—

	Ft.	In.
Bed No. 17 as	3	0
„ 16 „	0	6
„ 15 „	14	2

Bed No. 25 reaches up the hill to about 10 feet above the level of the surface at the bore-hole; then comes a bed of shale in which is a coal-seam about 2 feet 6 inches in thickness, followed by shales (in which there is another seam 3 inches thick), and these by flagstone on the summit.

On Whernside the section above the Main Limestone is:—

Whernside.

		FEET.	
MILLSTONE GRIT.	{	Sandstone (of Cable Rake Top) with a thin shale-band	50
		Shale	40
		Flaggy sandstone (above Pot in t' Fell)	60
		Shale, with many sandstone-bands towards the south	50
		Sandstone and flaggy grit with shale-bands	} 200
		Coal	
YORSDALE BEDS:—			
	Shale	8	
	Sandstone and shale	48	
	Main Limestone (p. 29).		

The coal was seen above Skelside whence we got the following section:—

Skelside.

		FEET.
	Flags.	
	Shale and COAL.	
	Grit	66
	Shale	8
	Sandstone	48

Section on the East Side of Widdale Fell.

MILLSTONE GRIT.	{	Sandstone with flags in the lower part	50
		Shale	30
		Sandstones and grit	80
		Shale with thin coal (1 foot or less)	35
		Coarse pebbly grit	50
YORSDALE BEDS:—			
	Sandy shales and shales with cherty bands	80	
	Main Limestone (p. 72).		

Section on the West Side of Widdale Fell.

MILLSTONE GRIT.	{	Flaggy sandstone	40
		Shale	25
		Sandstone	95
		Shale with coal, 1 foot thick, seen in the stream on the south of the Fell, but not worked	40
		Pebbly grit, about	100

Section between Dodd Fell and Hawes.

		FEET.	
MILLSTONE GRIT.	{	Sandstone on the top of the fell, over	50
		Shale	25
		Grit, coarse	} 140
		Sandstone, blocky	

YOREDALE BEDS:—		FEET.
Shale	-	} 60
Sandstone, 3 to 20 feet	-	
Shale	-	
Main Limestone (p. 68).	-	

At Buckden there are 470 feet of Millstone Grit immediately overlying the Main Limestone, viz. :—

		FEET.	
MILLSTONE GRIT.	{	Sandstone, forming an outlier on Buckden Moor, and capping Great Whernside* in the adjoining map on the east	70
		Shale	50
		Sandstone	50
		Shale	50
		Sandstone, varying from 90 to 60 feet, say	75
		Shale, varying from 100 to 150 feet, say	125
		Grit	100

The lowest of the beds is the grit of Grassington Moor. It forms the outliers on Old Cote Moor Top and on Cray Moss. It sometimes consists of two separate beds, the lowest of which is called the "bearing grit," because lead-veins are most rich in this bed on Grassington Moor. West of Yockenthwaite Moor a band of shale comes in between the grit and the Main Limestone, as may be seen at the head of Deepdale. A small outlier of Millstone Grit on Wetherfell consists of coarse pebbly grit on sandstone, and another of similar character occurs on Ten End.

COALS IN THE LOWER CARBONIFEROUS ROCKS.

In Wensleydale and at the head of Wharfedale there is generally a coal at the base of the Middle Limestone; this has been worked in several places, particularly in Wensleydale. There is also in many places a coal near the base of the Underset Limestone; and again there is one near the base of the Main Limestone, which has been worked on Cam, Widdale Fell (p. 51), and Whernside. There is also at times a coal on the top of the Main Limestone, as on Rise Hill, between Dent and Garsdale. In the Millstone Grit there are coals between the Bearing and Top Grits of Grassington Moor, and on or near the top of the Top Grit. The former has been gotten on Cam Moor, near Kettlewell. A coal, probably on the same horizon, has been worked on Pennegent. Coal has also been extensively worked on Fountain Fell, whose summit is covered with old coal-pits; and from the accounts of boring there it appears that there are no less than seven separate seams, the principal of which are respectively 2 feet 4½ inches, and 2 feet 6 inches thick. The last of these, however, is above the bore-hole. The Millstone Grit coals on Whernside and on Widdale Fell have been already mentioned. The seams mentioned above were worked in former days for domestic use, but now are only occasionally dug out for burning lime.

* Not the hill north of Dent, which is known as Whernside.

Professor Sedgwick writes: "It is said that they [the coal-beds in Dent] were first considered an object of profit in Kirthwaite. Early, I believe, in the last century a small *Statesman* called Buttermere found the bed of coal under the *upper Limestone* [the Main Limestone] of the Town-Fell; just under the last rise of the Crag. The bed appeared at first sight too thin to be worked for profit; but on examination it proved to be free from sulphur, and well fitted for the works of whitesmiths in Kendal. He therefore engaged the help of the country miners and carried on his work for years—conveying to Kendal, by a train of pack-horses (seventeen miles over the mountains), the coal which he drew from a bed not more than six or seven inches thick."*

* A Memorial by the Trustees of Cowgill Chapel. *Cambridge*: 8vo. 1868, p. 60.

CHAPTER VIII.—CARBONIFEROUS ROCKS—*continued.*

THE COALFIELD OF INGLETON AND BLACK BURTON.

By R. H. TIDDEMAN.

THIS Coalfield by an unfortunate accident of the division of the Ordnance Maps lies in four Quarter-Sheets, and the part in the map under review, though small, is a very important part. There are at the same time great difficulties in the way of an accurate diagnosis of some of the area, and on the whole an acknowledged ignorance will be safer than a rash confidence in dealing with these parts.

Commencing with what we know as absolutely certain we may say that so far as the exploration of the Coalfield has progressed it contains two good workable coal-seams, the Four-foot or Main, which is the best, and the Six-foot or Deep Coal, and that the former lies about 85 feet above the latter. Both of these beds have been worked along the outcrop from near Black Burton to a little south of Ingleton in numerous "hand-pits," and subsequently the Four-foot has been worked by deep shafts in several places.

The extent of the Coalfield is unknown and so far untried. It certainly does not exist west of Burton* nor further east than the Craven Fault near Ingleton, but of its extent to the north it is difficult to judge. The southern extent is of course well-defined by the worked outcrop, but not so the northern boundary; that can but be conjectural, considering the absence of sections and the thick spread of Drift to the south-east of Kirkby Lonsdale, Coal-Measures, however, being distinctly shown in Leck Beck.

Previous to the Geological Survey entering upon this ground all the rocks visible in Leck Beck below the Silurian area were regarded, in various Editions of Mr. Ruthven's Geological Map, as "Old Red" or "New Red." It is difficult to say what could have led to this conclusion, save the red colour of the beds. They are totally unlike the well-known so-called Old Red Conglomerate of Underley Park hard by and the similar beds occurring beneath the Mountain Limestone in many parts of the Lake District, and the variations in character, substance, and general appearance render them extremely unlike any Permian or Triassic Beds. A portion of the beds visible in the Greet from Ingleton downwards was also coloured in the same map as belonging to "Old Red" or "New Red," but a line of demarcation was drawn between these and the known Coal-beds. This line could not be recognised anywhere. There was no special change in the general character of these alternating beds to support a notion that there was a sudden change anywhere from beds of one age and character

* The Coal-seams of Farleton, Lowgill, Caton, &c., to the south and south-west belong to the Millstone Grit Series.

to those of another, and there was no alternative but to throw the whole of them into Coal-Measures and this was accordingly done. The same change was necessarily made in the classification of the Leck Beck beds.

The only further doubt that remained was the existence in the river between the two bridges at Ingleton of certain measures which contained calcareous beds. These consisted of gypsum or a highly dolomitized limestone. A specimen of this rock was analysed by Prof. E. Frankland, and shown to differ from dolomite merely in there being a slight deficiency in the proportion of carbonate of magnesia. The analysis follows.

Analysis of a sample of Limestone from Ingleton.

	Mean of two specimens.
Moisture at 100° C. to 110° C.	.30 per cent.
Portion soluble in water :—	
Volatile matter	.12
Mineral matter, containing .04 per cent. SiO ₂ , .08 per cent. CaO, and .03 per cent. MgO	.48
Portion insoluble in HCl, and containing 2.22 per cent. :—	
SiO ₂ , .59 per cent. Fe ₂ O ₃ and Al ₂ O ₃ , and .00 per cent. CaO	2.78
Portion soluble in acid :—	
Silica	.10 per cent.
Sesquioxide of iron	.36
Alumina	1.23
Oxide of manganese	traces
Phosphoric acid	traces
Lime	30.06
Magnesia	18.81
Alkalies	traces
Sulphuric acid-	.22
Carbonic acid -	45.51
	99.85
Loss on strong ignition	45.51
Carbonate of lime	53.69 per cent. { CaO 30.06 CO ₂ 23.63
Carbonate of magnesia	39.50 " { MgO 18.81 CO ₂ 20.69
Organic matter, traces only.	

Such beds do not occur in the well-known Coal-Measures further down stream, nor in the Burnley Coal-Basin. Limestones of a certain character, however, do occur in the Upper Coal-Measures in the Lancashire Coalfield near Manchester, and there seems no improbability that such calcareous beds should have been developed locally in the Coal-Measures anywhere. Moreover the sandstones and shales interbedded with these limestones in the Greet were identical not only in character but even in colour with the beds in the river lower down stream. The only conclusion possible was that these were all Coal-Measures, and that either those between the bridges were the same beds as those

below, but had thin limestones coming in, or that they were higher beds of the same series.*

The following are the only sections of any importance occurring in the small part of the Ingleton Coalfield which falls within the area of the Quarter-Sheet now under description.

Section sunk through in the Newfield Pits, Ingleton.

(Then belonging to Mr. T. Bracewell. Information furnished by Mr. E. Danson, manager.)

		THICKNESS.		DEPTH FROM SURFACE.	
		Ft.	In.	Ft.	In.
	Soil	2	0	2	0
Glacial Drift	Clay	9	0	11	0
	Fine dry sand	3	0	14	0
	Marl [Boulder Clay]	36	0	50	0
	"Leather" clay, sandy (laminated), with a few boulders	9	0	59	0
	Red marl	5	0	64	0
	Red rock } called "Crow Coal	2	0	66	0
	Grey rock } Rock"	2	6	68	6
	Crow COAL	1	3	69	9
	"Segar" clay	3	0	72	9
	Black shale	6	0	78	9
COAL ("MAIN" or "FOUR-FOOT")	4	0	82	9	
Fire-clay	2	0	84	9	
YARD COAL	2	0	86	9	
"Segar" clay	3	0	89	9	
Grey rock	42	0	131	9	
Ironstone-bands	2	0	133	9	
Grey rock	12	0	145	9	
Ironstone-bands	1	6	147	3	
Grey rock	12	0	159	3	
Black shale	0	6	159	9	
Blue "soapstone"	12	0	171	9	
SIX FOOT COAL	TOP COAL	1	6	173	3
	Dirt	0	4	173	7
	MIDDLE BED	4	0	177	7
	Dirt	0	5	178	0
	BOTTOM COAL	0	6	178	6

The following are the beds driven through in the Main Drift from Moorgarth Colliery, Ingleton.

Moorgarth Colliery.

(Information as above.)

	Ft.	In.
TOP COAL	0	5
CANNEL	1	7
COAL	2	4
Fireclay	1	9
Black "shiver"	0	3

* The late Mr. E. W. Binney, F.R.S., whose knowledge of Carboniferous as well as Permian and Triassic Rocks in the North of England was very considerable, kindly went to see them at my suggestion and said that he quite agreed with my conclusions. This, if it did not remove all doubt, at any rate relieved one of some responsibility.—R. H. T.

	Ft.	In.
YARD COAL	3	2
"Segar" clay	1	0
Black shale	0	9
Grey "soapstone"	2	0
Grey sandstone-rock	33	6

The drift began in the lower beds, was carried level and, by the dip (1 in 5), passed into the upper, as above.

A further drift was carried on through troubled ground to the N.E. It passed for 60 yards through stone and a bastard coal with black shale-roof. Then the following beds *nearly vertical* were crossed:—

Moorgarth Colliery.

	Ft.	In.
"Segar" clay	18	0
"Soapstone," red-cast	25	0
"Segar" clay	5	0
"Soapstone," red-cast	9	6
Grey rock	2	0
"Soapstone," red	5	0
"Segar" clay	10	0
"Soapstone"	23	0

Then the drift passed for 35 yards through "red soapstone" dipping at a low angle.

Section of Coal-Measures in a Gill near Yarlshber, Ingleton.

	Ft.	In.
Sandstone	66	0
Clay	6	0
Coal-smut	0	1
Sandstone, rather hard	3	0
Soft grey and purple shales, with reddle	7	0
" " " " harder	9	0
Sandstone	45	0
Red and white speckled soft sandstone (thickness unknown). Here comes a fault running N. 30° W. with quartz-pebbles in it.		
Fine light-blue clay well-bedded, with plant-remains.		
Coal, good	1	0
Seat-clay	1	0
Grey "soapstone" with small ferruginous irregular nodules	8	0

CHAPTER IX.—FAULTS AND MINERAL VEINS.

By J. R. DAKYNS, W. GUNN, and A. STRAHAN.

FAULTS.

THE north-western and south-western corners of this Quarter-Sheet include portions of the line of disturbance, usually known as the Pennine Fault. The name was first applied to the great dislocation which runs at the foot of the Pennine range on the east side of the Vale of Eden; but subsequently was made to include the system of faulting which extends from the south end of the Vale of Eden past Dent to near Ingleton, and lastly that which runs from near Ingleton towards the south-east, partly within this map. For the first length mentioned the fault runs about south-east with a downthrow west, for the second it runs about south-south-west with a downthrow east, and for the third about south-east with a downthrow west. The intermediate length therefore (*viz.*, that between the south end of the Vale of Eden and Ingleton) intersects the others nearly at right angles, and throws the strata in an opposite direction. The necessity which arose under these circumstances of distinguishing one portion of the fault from another has been partly recognised in the application of the name Craven Fault to that portion which runs south-east from Ingleton. The name Pennine Fault may be conveniently restricted to the part which gives rise to the Pennine range,* but it remains to find a term descriptive of the intermediate length. The part in question runs from the Eden above Kirkby Stephen past Cautley and Garsdale Foot, where it separates the Howgill Fells from the Carboniferous hills of Wild Boar Fell and Baugh Fell. Then entering this map it crosses Dent, and passes up the valley occupied by Barkin Beck, forming the boundary between the Silurian rocks of Middleton Fell, Barkin, and Barbon Fell, and the Carboniferous hills. Eventually it dies away near Leck Fell, in the same neighbourhood in which the Craven Fault comes into existence. One of the best known dales crossed by the fault is that of Dent, where also its peculiar effects are mostly fully exhibited. We shall therefore allude to the three dislocations as the Pennine fault, the Dent fault, and the Craven fault in the following pages.

Highly inclined or inverted along the Dent and Craven faults, the Carboniferous rocks lie nearly horizontally throughout the remainder of the area in this Quarter-Sheet, and are remarkably free from disturbance. The twist-up takes place usually at a quarter to half a mile distance from the fault, and so sharply that

* Phillips applied the name "Penine Fault" to the whole length of the dislocation from the Pennine range to Ingleton, but remarks "on arriving at Kirby Lonsdale the Penine fault suddenly turns to the E.S.E., and receives the name of the Craven Fault." *Geology of Yorkshire, 1836, part 2, p. 104.*

the strata pass from a horizontal to a vertical position within a space of a few yards (Fig. 4). Close to the fault we sometimes see the beds pass a few degrees beyond the vertical, so as to be inverted, and at the same time notice that the plane of the fault slants down to the west, under the Silurian rocks. The fault therefore belongs to the class known as "reversed faults." So far from allowing the strata to occupy a wider space, as happens in the case of a normal fault, it marks a line along which they have been compressed till broken, and have been partly thrust, the older (Silurian) rocks over the newer (Carboniferous) beds. The gills draining the west side of Greygarth Fell into Barkin Beck and Aygill (Quarter-Sheet 98 S.E.) best exhibit these peculiarities.

In the present map the fault runs for the most part under Drift, keeping about east-south-east near Hole House in Dent, but bending suddenly, near the river, to a few degrees west of south, and, after passing Gawthrop, to about south-west. At the bend it throws off a number of small faults, which run about S. 30° E. towards the head of Deepdale. These unlike the Dent fault throw the strata down westwards, excepting one of two nearly parallel fractures seen in Gastack Beck, which is a downthrow to the north-east. Gawthrop gills, Flinter Gill, and How Gill provide exposures of these smaller faults, and a small watercourse near Gawthrop follows the Dent fault for some yards so exactly that its west bank consists of Coniston, and its east bank of Carboniferous Limestone.

The Craven fault consists of two parallel lines of fracture, each with a downthrow west, and distinguished as the North and South Craven faults (Figs. 1 and 3). Between the two lies a mass of Carboniferous Limestone, dipping generally to the south-west at a high angle, but not infrequently turning over and dipping east or north-east near the North Craven fault. The position of this northern branch is got pretty accurately both in Jenkin Beck and in the Dale Beck, in both of which the thrown-down Carboniferous and the Silurian Rocks are seen near each other, but it is more fully exposed in Thornton Beck, at the angle north-east of Thornton Hall, where its course coincides with that of the stream for some distance. It hades at 30° or 35° from the vertical, and the beds near are a good deal smashed. A trial-level has been made here, apparently for lead, but without result. Further to the north-west the fault seems to divide, the main part going by the point marked 882, at a junction of roads, while a branch passes by Hunt's Cross, probably without much "throw," but marked by much dun limestone with calcite along its course.

The position of the South Craven fault is exactly given in Jenkin Beck, where we find sandstone (Coal-Measures) on the west side opposed to the limestone on the east, but north-west from this we infer its course from the ending off of the limestone along a well-defined line. There was an indication of shale having been got out in making the chimney of the Mealbank Limeworks, on the west side of the fault. South of Jenkin Beck the courses of both faults become obscure, owing to the Drift.

The throw of the North Craven fault seems greatest about Jenkin Beck (Fig. 3). Near it the section on the west side is somewhat complicated apparently by other faults, but a mass of shale seen in one place and apparently sandstone in another, indicate the presence of Yoredale Beds, which are opposed to Silurian rocks on the east side of the dislocation, so that the throw must be greater than the thickness of the Great Scar Limestone, or over 600 feet. A little to the east of the fault we find dun limestone along a north and south line. A similar vein, with traces of iron- and copper-carbonates, lies near the South Craven fault. Close by, on the north side of Jenkin Beck, a remarkable set of narrow joints, like a rough kind of cleavage, traverses the limestone, the planes striking N. 40 W. and dipping at 55° to the N.E.

MINERAL VEINS.

The only other fault of any importance, occurring in the area of this map, is that which crosses Burtsett High Pasture in a south-south-westerly direction; this fault throws down the beds on the east side, so that the Main and Underset Limestones of Bardale are repeated on Carlows. It dies out in Bardale; but northward it continues across the Ure, and is also a lead-vein. Lead-veins are worked on Middlesmoor, west of Kettlewell; and have in former times been extensively worked on Cam Pastures, north of Kettlewell. There are also many lead-veins on Hawkswick Moor. Many of these veins are merely open joints filled with spar and ore. Calcite, barytes, and fluorspar form the "vein-stone." Near the top of the Main Limestone on Buckden and Bishopdale Gavels* three "flots" of lead occur, which have been extensively worked. The mode of occurrence of the ore is on this wise: the white limestone is traversed by a number of vertical courses of magnesian limestone, known to the miners as "dun lime." These courses are of various breadths, some only a foot or two, others several yards, wide; they all trend nearly N.N.W., and at three different horizons lead-ore occurs between the dun and white limestone, and is followed and worked along the cheeks of the dun course. Dun limestone and lead-ore are in this part of the country so generally united, that wherever a course of dun limestone is found the miners search along it at the proper horizons in the strata in hopes of finding ore. Though the "dun lime" generally occurs in the shape of parallel vertical courses, yet it sometimes seems to form great irregular masses, and at others to lie in beds.

Mr. Dalton notes that the large pot-holes west of Pennegent, known as Jackdaw Hole, Hull Pot, and Hunt Pot, seem to be situated on lines of fracture, but that there is little or no displacement. In Hull Pot there occur traces of lead, zinc, and copper ores with calcite and barytes.

* This word would be more correctly spelt Gavlē.

Near Beckermonds there are one or two veins of copper-ore in the Carboniferous Limestone, trending N.N.E.

Sulber Nick probably marks the line of a vein. There are several small veins in the limestone on the north-west side of Ingleborough running in the same direction or E.N.E. A little galena seems to have been obtained from one of these at the spot on the map marked "Lead Mines." The two north of Black Shiver Moss have traces of spar, and the northern one barytes with a trace of copper. A poor vein runs in a north-north-westerly direction north of the spot marked "Lead Mines," but it cannot be traced across the bottom of the valley east of Dale House, though on the north side a vein having nearly the same direction has been tried north of Atkinson's Hull.

In Garsdale a small fault, seen in Blea Gill (near Dandra Garth), runs a little north of east with a down-throw south, crossing the gill about 30 yards from the road. It appears also in the cliff over the bend in the road a few yards further up the dale. A quartz-lode running N. 35° E. crosses the river near Scar House, and a second running N. 27° E. is exposed to view in Assey Gill in the Simonstone Limestone; the quartz contains small specks of copper-pyrite. The fault near the Garsdale coal-pits has been previously alluded to.

A similar vein has been found in Dent in the Great Scar Limestone in the gill which comes down from Coventree, and has been tried for copper about 150 yards below the road to Dent. Specks of copper may be seen also in a joint filled with calcspar in the "Marble" quarry near Great Combe on Crag Fell. The joint runs about east-south-east.

CHAPTER X.—SUPERFICIAL DEPOSITS.

By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and
A. STRAHAN.

GLACIAL DRIFT.

THE ordinary Glacial Drift of the district consists of coarse subangular and rounded detritus of local rocks. This is sometimes more or less rudely stratified, but perhaps is generally heaped together without arrangement. It is often piled up in hummocks, the longer axes of which are ranged in the direction of ice-flow, that is usually up or down the dales. It also often forms a spread in the bottoms and along the sides of the lower valleys, but is apt to be especially abundant at the junction of two large valleys, where it often completely covers the rocks to the height of some hundreds of feet above the stream in the angle between the valleys.

There is certainly more Drift in the basins of the Ure and Ribble than in that of the Wharfe. Thus the gentle slope of Aysgarth Moor is formed at its lower end of thick Drift, which in Bishopdale (Quarter Sheet 97 S.E.) takes the form of huge mounds of Boulder Clay trending north-east. Semmer Water is dammed up by Drift; and there is a great deal of Drift at the head of Raydale, while Bardale is well-nigh choke-full of Drift.

There are some fine striæ on rock at the head of Widdale, trending E. 35° N., at an elevation of more than 1,650 feet above the sea. In Wensleydale itself the general motion of the ice was finally down the dale, *i.e.*, towards the east, as is clearly shown by the shape of the ground. No rocks foreign to the district have been found among the boulders in Wensleydale or Wharfedale; nor in fact in any part of the area embraced by this map.

As mentioned above, the east side of Ribblesdale is so smothered in Drift that it is difficult to trace any subdivisions at all in the solid rocks; and connected with this is the fact that the watershed between the upper parts of Ribblesdale and Wharfedale is occupied by mounds of Drift, the longer axes of which point more or less along the cross-valleys, *i.e.*, from N.E. to S.W. Scratches trending S.S.W. were observed on solid rock in this neighbourhood, east of Ling Gill, near the Hawes and Settle road. In fact there are few places where the arrangement of the rubbish-heaps of the ice-sheet is better shown than at the head of Ribblesdale. We have here a part of the watershed between the Ribble and the Lune, which is crossed by the long railway-viaduct of Batty Green, near Ribblehead Station. The heaps lie in long, somewhat semi-ovoid forms, some of large size, and for the most part conform to the courses of the valleys. That the movement of the ice has determined their arrangement cannot be doubted,

partly from the reason just stated, and also because glacial striations, where found beneath them, usually coincide with their long axes. It appears by the arrangement of the Drift-mounds that a portion of the ice forming in the present Ribble-basin did not work down to lower levels by way of Settle, but branched off across the watershed down the Dale Beck towards Ingleton. This is shown by the mounds as viewed from the first railway-cutting south of Ribbleshead Station, where the mounds and underlying striations are pointing from Gearstones Inn, and go on, over rather higher ground, to the south-west along the western side of Ingleborough. Another group of glacial striations,* along the east side of the mountain, runs from about 1,200 to 1,400 feet in elevation, those to the north being lowest. The first is about 400 yards W. 30° S. from Hellan Pot, and runs S. 10° W. The next two lie about a mile further south on the main mass of the Limestone. These are also S. 10° W., the furthest being beneath a limestone-boulder. Another, under Drift at the boundary between Fell Close and The Allotment, where a cart-track joins it, ranges S.S.W. A fifth, about a quarter of a mile south-south-west of this, at a point marked "Water-swallow" on the six-inch map, ranges S. 35° W. Again, 115 yards north-east of the mouth of Long Kin Cave are striations pointing S. 50° W. These last three localities are above the main mass of the Limestone. These all appear to be connected with a range of moraine-like mounds which curve with the striations.

In the Ribble-valley about Horton there is a fine set of Boulder Clay ridges or drumlins. Those on the east side of the valley have a general tendency towards a south-south-westerly direction, and those on the west side towards the south-south-east, the latter coinciding more nearly with the majority of the glacial striæ on the rocks in the valley thereabouts. There is a cutting, 40 feet deep or so, through one of these ridges, about 600 yards south of Horton Station; and the underlying rock is finely glaciated. There is an interesting case here of deviation of direction of striæ in front of a scar (now concealed by Boulder Clay); for the striæ turn eastward along the face of the rock, and gradually surmounting it, bend round towards the south so as to recover their general direction. One of the best glaciated rock-surfaces in the country occurs among the Silurian rocks, south-west of Crummack, and close up to the Scar Limestone.

Glacial Drift probably occurs as high as 2,000 feet on the south-east side of Ingleborough, and it may be a good deal higher, for under the thick peat which covers much of the Main Limestone of Simon Fell, there seems to be a kind of Drift, principally made up of angular sandstone-blocks, partly embedded in clay. The same kind of Drift occurs in a patchy form over a good deal of the Scar Limestone about Lead Mines Moss and on

* This group was first noticed by Mr. Tiddeman in 1871, *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 471. 1872.

the south side of Ingleborough. In the stream above Crina Bottom loose local Drift is seen up to 30 feet thick, which however contains scratched boulders of limestone.

The distribution of the greater portion of the Drift around Ingleborough has been already noticed. It is thin and patchy over the lower part of the Silurian area in Chapel-le-Dale; thicker and more continuous in the narrow part below God's Bridge.

On the northern abutment of Ingleborough the Drift reaches in places to over 1,600 feet on the east side, and nearly to the same height on the west. As we proceed up the Dale Beck the rocks become more hidden by drifts, and when we approach the viaduct these seem to be more of a mixed character than below; nests of sand alternate with till and laminated clay, and give very rough wet pastures.

Beneath the viaduct and on both sides of it is a flat alluvial spread of laminated clay which is on the watershed. It is very thick, and gave much trouble to the contractor when building the foundations.

The numerous glacial markings in Chapel-le-Dale run generally south-west, parallel to the direction of the valley. Most of them are on the Silurian Rocks, but a few occur high up on the limestone of the south side, mostly under perched boulders; and at Souther Scales Scars some were noticed by Mr. Tiddeman at an elevation of 1,150 feet, running south-west under Drift, in a swallow-hole called Braithwaite Wife Hole. Some of the scratches marked south and south-east of Simon Fell occur under boulders. The ice here seems to have skirted the higher ground; for as mentioned above its direction of movement west of Selside was S. 10° W., but further south we find it generally about S.S.W.

Most of the boulders mentioned above as occurring on the bare limestone are of limestone. The largest of these, lying south-west of Hurnel Moss, is called the Harryhorse Stone. Boulders of Carboniferous sandstone, however, are pretty common on the limestone, but they are mostly small. The largest we have noticed occurs on Moughton, south of the foot-track from Bee Croft Hall to the head of Moughton Lane, and about equidistant from both. It measures 3 × 3 × 2½ feet, and, standing alone on the bare limestone-plateau, forms a conspicuous object. A large boulder of Carboniferous limestone, measuring 12 × 9 × 5 feet, occurs west of Skirwith in Chapel-le-Dale, and there are many others both of limestone and of Silurian rocks scattered about the fields near, which have come from some distance up the dale, especially boulders of a peculiar coarse conglomerate which crosses the valley in a band at Twisleton Dale House. At White Stones, south of Simon Fell, lies a mass of white encrinital limestone, about 70 yards long and 40 yards in greatest breadth, probably a portion of the Main Limestone from the top of the fell, brought hither by the ice-sheet. To the south of this a long ridge of Drift stretches to the south-south-west, looking like a

lateral moraine of the Fell Beck valley, but it is probably only an ordinary drumlin.

In Kingsdale above Twisleton Hall there are thick masses of Drift, several drumlins on the east side ranging S.S.W.; and on the west side of the beck above Thornton Force there is a horse-shoe-shaped ridge of Drift with its convexity pointing up the valley. At the head of the dale, on the summit of the pass into Blea Gills, glacial scratches about 1,700 feet above the sea, trend N. and S., or N.E. and S.W.

The description of the Drift given above applies in all respects to that in Dent and Garsdale. It is purely local, consisting of more or less stony clay, formed from the grinding-up of Carboniferous shale and sandstone. The finely developed drumlins which run up to about 1,100 feet above the sea on Brown Mea and Brown Moor, are arranged with their longer axes in a nearly east and west direction, this being the trend of the dales of the neighbourhood. To the west where Garsdale and Dent join Lonsdale, which runs north and south, the drumlins also bend round to that direction. The same change is observable also in Deepdale, Kingsdale, at Dent Head, and in Little Dale under Whernside. In all these the drumlins run north and south, so long as they lie within a valley having that direction. They attain also a great height above the sea, amounting to 1,800 feet on the south-eastern side of Crag Fell, and to 2,000 feet on Blea Moor.

In one case in Dent, near Low Barth, the Drift becomes more gravelly than usual, and assumes the esker-like form so often seen in glacial gravels. Though there is no section to show the nature of the deposit clearly, the shape was considered sufficient evidence to justify the hillock being coloured on the map as gravel.

A more interesting case of stratified Drift-Gravel occurs above Arncliffe on the north side of Darnbrook Beck. The beds are inclined at an angle of deposition of 20° to the E.S.E. This patch of gravel lies at a height of 1,150 feet above the sea, on the very brow of the steep slope running down to Cowside Beck.

In some cases the Drift takes the peculiar form of ridges of loose sandstone-débris, piled up, much like lateral moraines, at a short distance from the steep slopes. Ridges of this character occur in Great Combe under Crag Fell (near Dent) and under the steep eastward face of Whernside. In the first case the ridges run across from point to point of the Combe, so as to enclose a hollow known as Combe Bottom, now partly filled up with peat. On Whernside the ridges start from some great piles of slipped shale and sandstone just below the highest point of the hill, and curve round to the north on a platform of shale supported by the Main Limestone. They run for about 800 yards nearly parallel to the steep face from which they start, at a distance of about 300 yards from it, so as to enclose a large hollow with two little tarns, and known as Greensett Moss. Patches of sandstone-

débris occur also lower down the hill, overspreading the shale and limestone-outcrops. They are above the level of, and different from the drumlin-drift described above.

Though these ridges and heaps of rubbish resemble moraines in form and composition, they are not in such places as would have been occupied by a glacier. Neither in Great Combe nor on Whernside is there sufficient gathering ground for the formation of a glacier, and in the latter case the ridges run parallel to the steep slope instead of keeping straight down the hill. They appear more probably to be due to avalanches of snow down the steep slopes. Avalanches of sufficient violence to transport large rocks and to knock down farm-buildings have been known to occur in the dales. According to Sedgwick they were in his time called "Gill-Bracks" or "fell-side Bracks," by the old people in Dent. None of the shepherds now living in the dale remember any snow-slip of sufficient importance to deserve the name of avalanche, but they point out several steep slopes where it has been found impossible to maintain stone-walls on account of the general movement of snow and soil after frost, and in several cases where wire-fencing has been laid straight up such a slope the posts have been snapped off and the wire gathered in a tangle at the foot of the slope after a heavy snow-fall.

A notable example of a "gill-brack" occurred about the 28th of January 1752 and was described by an eye-witness in the letter of which a copy is subjoined. The letter was first printed incorrectly in the Proceedings of the Cambridge Philosophical Society, afterwards more correctly in the "Cambridge Chronicle" (Dec. 9th, 1865), and lastly by Sedgwick in "A Memorial by the Trustees of Cowgill Chapel (1868)." The original is now in the possession of Prof. T. McK. Hughes, to whom also Sedgwick was originally indebted for it. It was addressed to "Christor Thistlethwait, Hosier, Att Aysgarth in Wensleydale," but the address has long since become illegible.

"Habourgill y^e 6th of the 2nd mo^h 1752.

"Dear Bro. and Sist,—

"These few lines I hope will find Excuse for it's not Without a Cause that I have written no Sooner to you for I fully purposed to have Seen you a Considerable time since, but Now as things are at present I have Lost all hopes of Coming yet thro the good providence of Heaven we are all Alive and preatty well in health which is more than Could be well expected Considering what Dismall Time it has been with us in Dent I hope I shall never Live to see the Like again for we had the greatest Storm of wind and Snow that continued for above a Week with very Little intermission so that all the water Courses both in the Mountains and Elsewhere was Made Levell the Like Never being remembered for it Excited the Curiosity of Several persons to view them with wonder and astonishment yet Little thinking that the Consequence would have been so Tragical to Many for at the breaking up of the Storm* it began to rain Exceedingly in the Evening which Continued all Night and the next Day to that degree that by 11 a'clock the Dismall Scéen began for the Snow in y^e the Courses being no Longer able to Sustain the great quantities of water all began to Slide Down the Mountains together with incredible Swiftness Driving

* "Storm" here signifies frost.

great rocks Stones and Earth all before it Roaring Like Claps of Thunder which Made us run out of doors to see what was Coming upon us & we ran to Look at the Gill and we directed our sight (by the Noise that it Made) the right way and the frightfulness of the appearance at the very first Sight (which was when about the middle of the pasture) Made us run for our Lives and we got no further than from the yet* to the Sycamore Trees, before the Stable peat-house and all the Calf parrack† and Cow parrack was an heap of the Most Shocking Ruins that ever your Eyes beheld and I believe from the first Sight of it when it was Coming till all was overturned was Less than the $\frac{1}{2}$ of a minutes time it has brought Rocks Down past the Middle of the Houme Which has gone through the peat house and Stable that I think three or four Yoke of Oxen Could not be able to Move the poor old Horse was Crushed to pieces in a moment, Nothing but the good providence of God has preserved us from perishing for the Amazing to think how the Barn Stood the Violence of the Shock the water run round our dwelling house Broke down the gardin wall and Continued running thro it till Next day in the Morning So that its become a bed of sand it was about 11 aclock when this hapned and went from place to place Not knowing where to be Safe expecting every Moment More of the Like Nature which accordingly hapned for I think in the space of two hours the face of things was so Changed that one scarcely could have known them for they Came down almost Every Slack (so Called) Carrying all the walls before them so that we were obliged to run from one place to another to Escape their fury which was with difficulty for it Continued raining Extreanly that we wear wet to the Naked Skin not darsing to Come in any house And it drawing towards We resolved to make an attempt to get to Brother John's and accordingly set forwards and got up at our pasture head on to the Moor and with difficulty got over harbourgill and so forwards towards Munkeybeck but we knew that the bridge was broke down So that we must be obliged to pass it somewhere on the Moor And we waded throw the water And Snow till we were almost Spent in Extrean wet and Fateagne And at Last Got over a Little below where our peat fell is tho with very Great hazard of our Lives at Last; My poor, old Father and betty being almost quite Spent he having only one Shoe on one foot the greates part of that time then when we were got over it gave us some fresh encouragment and we arrived at Bro: Johns Just before it was dark where we were thankfull to see the faces of one another in a place of More Safty we went three Nights sucessively to bro Johns to Lodge Not darsing to stay about the old place. Old Francis Swinbank and Thomas Stockdals whol family perished in a Moment about the same time that the thing hapned with us being seven in Number Likewise John Burton Stone house had a Barn swept away and a Cow killed. I hope these few broken hints will be excused for I am not very good at writing at this time All being so in confusion so Greatly desires You would Come to see us as soon as well Can for our Love is Very Much towards you. You perhaps May think I have outstretched but if you please to Come your Eyes will Convince you to the Contrary. For I have Not told you one half So shall Conclude your very Loving Brother

“THOMAS THISTLETHWAIT.”

“Betty's kind Love is to you both but S^r in perticular.”

The funeral of the victims of this catastrophe is recorded in the Parish Register of Dent as having taken place on 31st January 1752. It is perhaps worth noting that Thistlethwait and his party must have crossed Monkey-beck close to the point where the

* Gate.

† “Parruck, or parrock, is a pure old Anglo-Saxon word, of which the modern word paddock is a vile corruption.” Sedgwick. A Memorial by the Trustees of Cowgill Chapel, Cambridge, 1868, p. 81.

stream is crossed by the Midland Railway, that is at the northern end of the platform of Dent Station.

A peculiar form of Drift, the like of which probably occurs in many other places, was specially noticed on Leck Fell. The lower part of the hill is almost completely covered by a local till consisting of very sandy clay enclosing vast numbers of fragments of Yoredale sandstones. These often occur locally in such numbers as practically to enable water to flow through the Drift, the effect of which is to gradually wash away the finer material and leave nothing but a mass of grit-blocks.

These masses of grit are not due to mere weathering out nearly *in situ*, as might be at first supposed; for by far the largest examples of them occur further west on the Carboniferous Limestone, where there is no grit near to form such masses.

A remarkable glaciated rock-surface has been exposed in a cutting on the Midland Railway on the northern margin of this map (about one mile south of Hawes Junction). As clearly appears from the deep grooving of the many ledges and faces both horizontal and vertical, presented by the rock, the movement of the ice has been *up* the dale, though from the direction of the Drift-transportal, we should have inferred an ice-flow down the dale.

Striæ have also been observed by Prof. T. McK. Hughes, running east and west in the bed of the river 150 yards below Kirk Bridge in Garsdale, on the Hardraw Scar Limestone. On Mossdale Moor near Sikes Pits Gill, the coarse grit overlying the Underset Limestone is well-rounded, probably by glaciation, though striæ are not actually visible. The ice-flow appears to have been here about east-north-eastwards, but the evidence is scanty.

ALLUVIUM, RIVER TERRACE, AND PEAT.

By W. GUNN.

THE only alluvial patches worth notice in the Ingleborough district occur in the Ribble valley near Horton, and in the valley of Thornton Beck about Ingleton. The largest area along the Ribble is found below Horton, and forms part of an extensive flat, most of which lies in the sheet to the south of this (92 N.W.), and which flat seems to be the site of an old lake. The alluvial deposit of the Ribble consists of sand and gravel, with silt on the wide flat before mentioned. There is no distinct trace of any terrace above the more modern Alluvium of the main stream, but such terraces exist along two of its tributary streams, Brans Gill which joins the Ribble at the New Inn, and Horton Beck, which runs past the village. East of Horton Bridge the terrace of the latter stream appears about 25 feet above the water.

In the Ingleton area, a lake-like expanse of Alluvium has been formed by Thornton Beck, in Kingsdale, above a barrier near

Raven Ray through which the stream has cut a ravine. In the valley of Ingleton Beck there are some rather wide alluvial flats between God's Bridge and Beezley's, with some doubtful traces of terraces near Twisleton Dale House. Where the two streams leave their ravines and come together at Ingleton there is a great thickness of alluvial material at a considerable height above the river. On Thornton Beck, where the South Craven fault crosses, we find on the east side first the ordinary alluvial flat, reaching to a few feet above the bed of the stream; next a low terrace, about 20 feet above the stream at its highest part; then a steep bank, 30 feet high or so, on the top of which lies a narrow terrace of old river-gravel. On the Ingleton Beck at the north end of the village, there are three distinct flats of the lower Alluvium below that of the high terrace, and on the south of the railway and west of the river there are four of these terraces, rising a few feet each, on the lower alluvial flat. These are bounded by a high bank, above which comes a high gravel-terrace 50 feet or more above the others. The lower part of the village, including the church, is built on this high gravel-terrace, which also forms the high flat on the west of the river near the railway-station. Some gravel-pits south of the station, and 15 to 20 feet deep, expose well-washed and rounded gravel. A peaty flat of some size, west of the station, appears to be the site of a lake or marsh, hollowed out in the high terrace. The high terrace on the east side of the river extends a long way to the south of Ingleton, but has been a good deal denuded.

There is much hill-peat on the high ground in places. It is thickest on the south side of Simon Fell, both on the limestone and on the high sandstone-plateau. A good deal also occurs on the slopes on either side of the valley of Fell Beck, and among the streams on the west side of Simon Fell.

Over the bare limestone-plateaus peat forms only where there are patches of thin Drift (mostly formed of Carboniferous sandstone), and that generally in hollows. There are many small patches of this peaty Drift on Moughton to the west of Horton, and on the limestone-plateaus of White Scars, west of Ingleborough.

Trees seem to have grown formerly at a far greater elevation than at the present day. Trunks may commonly be found in the peat-filled hollows high up on the fell-sides. Birch occurs in Greensett Moss, on the east side of Whernside, at 1,950 feet above the sea.

APPENDIX.

LIST OF THE MORE IMPORTANT PUBLICATIONS ON THE
DISTRICT.

By W. GUNN.

1802.

PLAYFAIR, J.—Illustrations of the Huttonian Theory. 8vo. *Edinburgh*. pp. 217-219.

1821.

SMITH, W.—Geological Map of Yorkshire. 4 sheets.

1829.

PHILLIPS, J.—On a Group of Slate Rocks ranging E.S.E. between the rivers Lune and Wharfe, from near Kirby Lonsdale to near Malham. *Trans. Geol. Soc.*, ser. 2, vol. iii., p. 1.

1835.

SEDGWICK, A.—Description of a Series of Longitudinal and Transverse Sections through a portion of the Carboniferous Chain between Penigent and Kirkby Stephen. *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 69.

1836.

PHILLIPS, J.—Illustrations of the Geology of Yorkshire. Part 2. The Mountain Limestone District. 4to. *London*.

1849.

FARRER, J. H.—On Ingleborough Cave. *Quart. Journ. Geol. Soc.*, vol. v., p. 49.

1852.

SEDGWICK, A.—On the Lower Palæozoic Rocks at the base of the Carboniferous Chain between Ravenstonedale and Ribblesdale. *ib.*, vol. viii., p. 35.

———.—On the Classification and Nomenclature of the Lower Palæozoic Rocks of England and Wales. *ib.*, vol. viii., p. 136.

1853.

PHILLIPS, J.—The Rivers, Mountains, and Sea Coast of Yorkshire. 8vo. *London*. Ed. 2 in 1855.

———.—A Map of the Principal Features of the Geology of Yorkshire. 8vo. *York*. Ed. 2 in 1862.

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